U.S. FISH AND WILDLIFE SERVICE

ROCKY MOUNTAIN ARSENAL NATIONAL WILDLIFE AREA

FISCAL YEAR 1992 ANNUAL PROGRESS REPORT

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

February 12, 1993

APPENDICES A - C

by

The U.S. Fish and Wildlife Service
Rocky Mountain Arsenal National Wildlife Area
Building 111
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LIST OF APPENDICES

Rocky Mountain Arsenal Deer Project:

PATTERNS OF COEXISTENCE FOR SYMPATRIC MULE AND WHITE-TAILED DEER ON THE ROCKY MOUNTAIN ARSENAL, COLORADO

ANNUAL REPORT

1 January 1992 to 31 December 1992

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ABSTRACT

Thirty-three months of field work have been completed at RMA. Winter 1991-1992 populations were estimated at 513 (95% CI = 501-530) for mule deer and 123 (95% CI = 118-131) for white-tails. Early winter 1992-1993 mule and white-tailed deer population estimates are estimated at 645 and 134 respectively. A total of 77 fawns were captured during spring of 1992. Fawn survival was greater in mule deer compared to white-tailed deer. Over 5,300 location estimates have been collected on 37 adult deer on RMA. Formal management recommendations and protocols for monitoring RMA deer populations will be formulated at the completion of data analysis.

REVIEW OF PROPOSAL AND OBJECTIVES

Five primary objectives were presented in my Ph.D. research proposal dated January 1991. Objectives 1 - 4 address the patterns of coexistence between sympatric mule and white-tailed deer (Odocoilius hemionus, and O. virginianus, respectively), while the last objective is to provide management recommendations to U.S. Fish and Wildlife Service (USFWS) and U.S. Army personnel concerning deer management on Rocky Mountain Arsenal (RMA). Specifically these objectives are:

1. To determine interspecific relationships between sympatric mule and white-tailed deer on RMA.
2. To determine the intraspecific interactions of mule and white deer on RMA.
3. To determine recruitment and adult mortality for sympatric mule and white-tailed deer on Rocky Mountain Arsenal.
4. To compare sympatric mule and white-tailed deer population statistics from RMA with allopatric and sympatric mule and white-tailed deer population statistics not on RMA.
5. To provide management recommendations and protocols to USFWS and U.S. Army personnel concerning mule and white-tailed deer populations and habitats on Rocky Mountain Arsenal.

Data collection revolves primarily around using radio telemetry techniques that quantify the location of telemetered individuals. In particular, the proposal calls for using telemetry to visually locate individual animals. Once located, data including date, time, habitat type, animal activity, group size and composition, and interspecific distances are recorded. In addition, the proposal calls for collection of feces for diet composition analyses, and site specific vegetation sampling of areas used by telemetered individuals. Included in the telemetry objectives of the proposal is the capture of 50 fawns (25 of each species) for purposes of estimating fawn recruitment for both species of deer.

Statistical analyses of these data include inter- and intra-specific comparisons of habitat use, diet composition, and spatial use patterns using a Chi-Square test of homogeneity (Iman and Conover 1989. Specific niche comparisons are to be analyzed utilizing the procedures of Petraitis (1979).

RESULTS

Demographics

Fourteen ground and 2 aerial surveys were conducted during spring and fall, 1992 (Table 1). Buck:Doe:Fawn ratios averaged 64:100:83 and 61:100:72 for mule and white-tailed deer respectively. Winter 1991-1992 populations were estimated at 513 (95% CI = 501-530) for mule deer and 123 (95% CI = 118-131) for white-tailed deer. Early winter 1992-1993 mule and white-tailed deer population estimates were 662 and 135 respectively. Population estimates over 4 years suggest that mule deer numbers are increasing whereas white-tail numbers fluctuated (Figure 1).

Table 1. Results of ground and aerial deer composition surveys conducted on Rocky Mountain Arsenal during 1992.

SPECIES	JULIAN DATE	ANIMALS COUNTED ♂♂	♀♀	FF	UU	ΣΣ	RATIOS ♂♂	♀♀	FF
MULE DEER	92034	67	108	89	3	267	62	100	83
	92082	66	88	74	7	235	75	100	84
	92117	30	77	58	3	168	39	100	76
	92275	22	72	55	4	153	31	100	77
	92281	52	70	43	2	167	75	100	62
	92309	48	68	55	7	178	71	100	81
	92321	40	33	12	2	87	122	100	37
	92322	36	62	55	3	156	58	100	89
	92323	49	60	46	0	155	82	100	77
	92344	60	97	99	7	263	62	100	103
	92345	54	94	99	11	258	58	100	106
	92354	38	85	65	11	199	45	100	77
	92355	--	--	--	--	405	--	--	--
	92356	53	91	93	13	250	59	100	103
	92357	--	--	--	--	390	--	--	--
	92358	57	106	110	6	279	54	100	104
WT DEER	92034	5	22	16	4	47	23	100	73
	92082	13	31	16	1	61	42	100	52
	92117	17	27	16	8	68	63	100	60
	92275	7	22	13	6	48	31	100	59
	92281	7	15	10	7	39	47	100	67
	92309	5	13	9	1	29	39	100	70
	92321	12	9	11	1	33	133	100	122
	92322	11	15	8	1	35	73	100	53
	92323	10	13	12	3	38	77	100	93
	92344	19	25	18	2	64	76	100	72
	92345	8	24	20	5	57	34	100	84
	92354	11	29	18	0	58	38	100	63
	92355	--	--	--	--	87	--	--	--
	92356	19	28	17	0	61	68	100	61
	92357	--	--	--	--	81	--	--	--
	92358	10	22	17	1	50	46	100	78

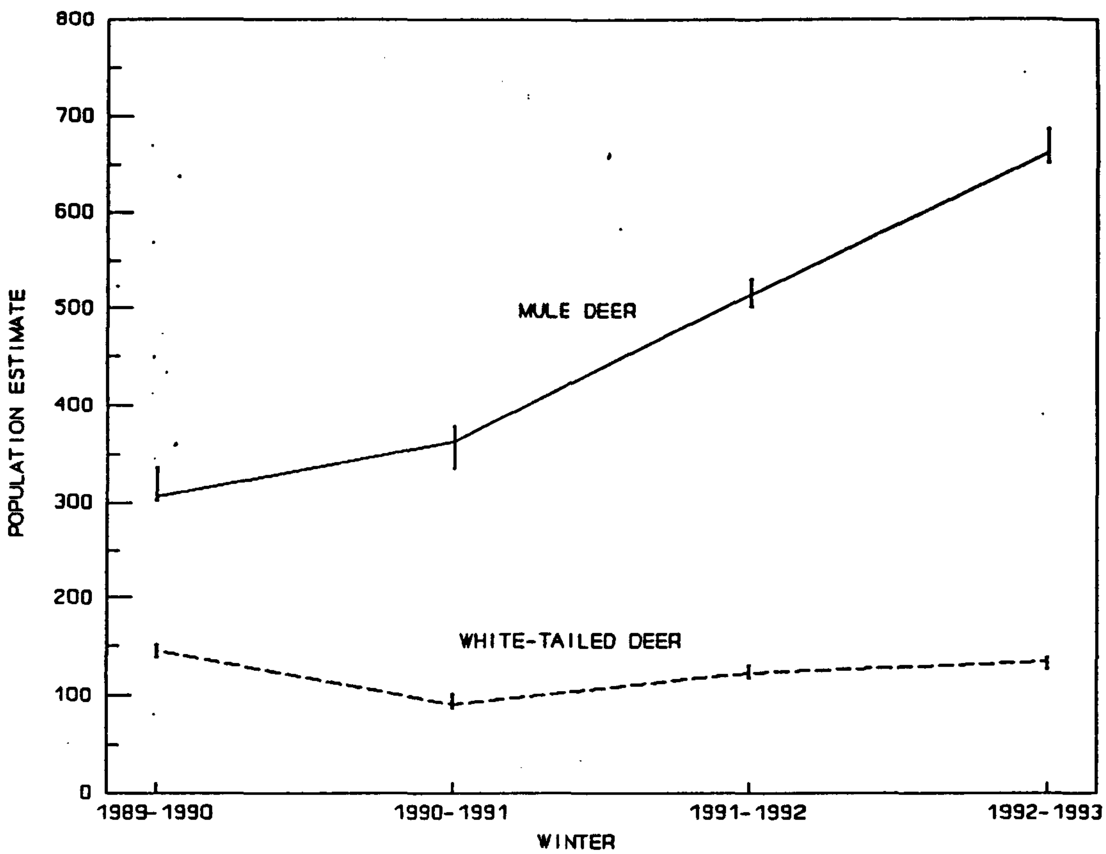

Figure 1. Mule and white-tailed deer population estimates from 1989 - 1992 on Rocky Mountain Arsenal, Colorado. Winter 1992-1993 estimate is based on incomplete counts.

A total of 77 fawns (48 mule deer, 29 white-tailed deer) were captured during spring of 1992. One set of mule deer and 3 sets of white-tailed deer triplets were observed. Survival to 30 days for fawns captured during 1991 and 1992 (83 mule deer, 37 white-tailed deer) was greater (X^2 = 8.6295, P = 0.003) for mule deer (s = 0.661) than for white-tailed deer (s = 0.34) (Figure 2). Predominate cause of death for both species was coyote predation.

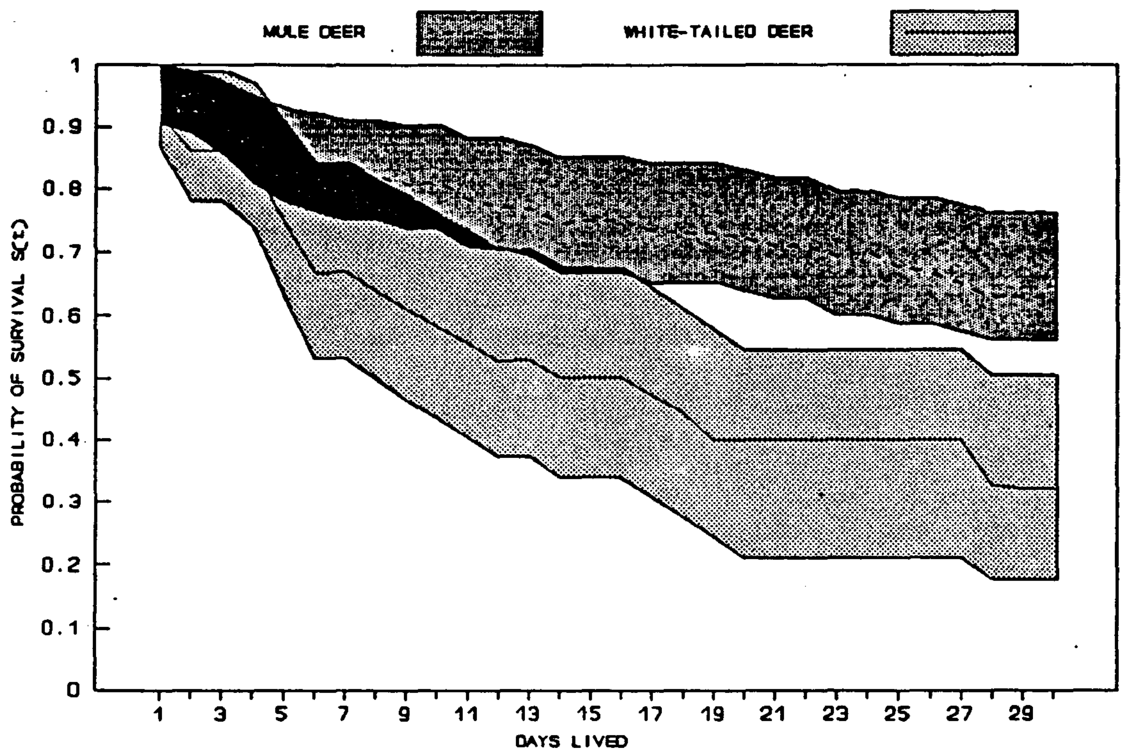

Figure 2. Probability of survival from birth to 30 days for 120 mule and white-tailed deer fawns on Rocky Mountain Arsenal, Colorado, spring 1991, and spring 1992.

Radio-telemetry

Over 5,300 location estimates have been collected on 37 adult deer (23 mule deer, 14 white-tailed deer) on RMA. Convex polygon home range area varied from 27.5 ha to 1336.9 ha for mule deer ($\overline{x}$ = 268.26) (Table 2), and 14.7 ha to 3591.6 ha for white-tailed deer ($\overline{x}$ = 288.40) (Table 3). Statistical tests for seasonal home range fidelity and interspecific overlap have not been conducted yet.

Table 2. Convex polygon home range area (ha) by frequency, year, and season for mule deer radio-tracked on Rocky Mountain Arsenal, Colorado.

	YEAR 1[1]				YEAR 2				YEAR 3		
FREQ	SPR[2]	SUM	FAL	WIN	SPR	SUM	FAL	WIN	SPR	SUM	FAL
2	102.2	99.9	96.3	152.8	99.8	101.2	99.0	261.0	324.9	35.5	122.7
3	362.3	93.6	28.0	137.1	101.9	73.1	92.4	337.4	72.0	156.4	54.2
4	103.2	.[3]	119.2	.	.	.	.	.	.	.	.
6	209.0	57.2	324.7	153.6	241.5	245.4	.	.	.	.	.
7	209.4	170.9	153.4	38.6	151.6	270.5	89.0	.	.	.	.
9	220.5	163.9	145.1	115.6	221.3	68.7	79.1	505.8	109.0	45.5	78.9
10	271.5	197.4	167.1	266.0	.	.	.	.	.	.	.
13	147.4	235.5	362.4	50.3	148.8	298.8	182.8	357.0	168.7	49.0	87.7
14	778.7	236.6	622.7	537.8	652.6	746.6	823.7	407.0	768.0	170.2	99.3
18	125.7	53.9	248.5	137.8	324.3	52.4	57.8	323.9	270.7	60.2	144.5
20	231.7	55.4	1203.4	97.3	338.0	55.4	656.4	839.3	559.2	294.9	168.2
41	.	.	.	42.7	82.5	31.7	29.6	214.0	66.5	43.5	14.0
43	.	.	.	138.0	86.1	188.4	57.1	182.8	297.2	78.0	97.3
47	.	.	.	87.3	112.1	77.1	223.9	147.0	.	.	.
48	.	.	.	.	503.0	27.5	50.3	555.6	339.2	34.8	57.0
52	.	.	.	.	533.0	213.7	300.3	300.1	306.5	93.9	252.7
53	.	.	.	189.1	401.8	134.0	347.9	298.1	406.1	147.4	369.9
54	.	.	.	.	186.3	224.8	257.7	363.6	940.9	307.2	298.2
55	.	.	.	.	627.9	63.1	282.4	146.8	1063.9	606.6	1169.0
56	.	.	.	.	903.5	353.3	96.4	228.8	499.7	265.3	21.6
58	.	.	.	204.0	977.7	1336.9	506.4	323.1	1006.7	139.2	948.7
60	.	.	.	.	373.6	285.1	554.0	279.4	670.5	474.9	308.0
61	.	.	.	.	550.8	307.3	288.4	.	.	.	.
♀ $\bar{x}$ =	251.05	136.43	315.53	150.38	235.65	172.06	203.43	375.53	297.54	96.80	92.38
n =	11	10	11	13	13	13	12	11	10	10	10
♂ $\bar{x}$ =	.	.	.	196.55	569.33	364.78	329.19	277.13	699.19	290.64	481.16
n =	.	.	.	2	8	8	8	7	7	7	7
♀♂ $\bar{x}$ =	251.05	136.43	315.53	156.53	362.77	245.47	253.73	337.26	462.96	176.62	252.46
n =	11	10	11	15	21	21	20	18	17	17	17

[1] Year 1 = 1 March 1989 - 28 February 1990, Year 2 = 1 March 1990 - 28 February 1991, Year 3 = 1 March 1991 - 30 November 1992.

[2] Spring = 1 March - 31 May, Summer = 1 June - 31 August, Fall = 1 September - 30 November, Winter = 1 December - 28 February.

[3] Insufficient observations to determine home range, animal not alive during this season, or animal not part of telemetered population yet.

Table 3. Convex polygon home range area (ha) by frequency, year, and season for white-tailed deer radio-tracked on Rocky mountain Arsenal, Colorado.

	YEAR 1[1]				YEAR 2				YEAR 3		
FREQ	SPR[2]	SUM	FAL	WIN	SPR	SUM	FAL	WIN	SPR	SUM	FAL
1	449.7	321.2	602.5	249.3	493.7	101.5	156.8	426.8	117.1	58.9	90.5
5	419.0	29.6	153.4	.[3]	168.2	64.1	56.8	71.7	202.7	36.0	51.5
8	497.5	3591.6	185.0	613.8	547.8	.	.	.	.	.	.
12	167.1	67.3	120.0	255.8	123.3	220.9	93.1	409.2	76.7	600.6	62.1
15	234.7	262.1	325.2	247.0	96.0	37.5	61.9	332.5	75.7	79.9	32.0
16	304.6	97.4	99.1	490.2	194.3	52.0	43.1	646.9	92.7	12.6	82.1
17	205.1	65.2	73.2	455.8	125.3	98.5	41.1	150.6	48.3	86.3	116.9
42	.	.	.	.	837.2	405.6	311.7	295.1	14.7	292.3	353.8
45	.	.	.	.	863.5	75.6	194.3	228.7	175.9	448.5	128.8
46	.	.	.	252.6	210.6	46.2	85.4	47.5	304.5	160.7	140.2
49	.	.	.	.	1219.3	769.5	556.6	298.5	.	.	.
50	.	.	.	.	187.6	325.3	144.3	305.8	154.6	108.2	217.4
51	.	.	.	.	885.2	249.4	235.9	244.2	402.9	109.2	.
59	.	.	.	.	612.2	264.2	286.7	297.1	245.4	124.2	351.8
♀ $\bar{x}$ =	325.39	633.49	222.63	366.36	365.99	122.43	116.02	289.89	123.14	197.31	117.54
n =	7	7	7	7	10	9	9	9	9	9	9
♂ $\bar{x}$ =	.	.	.	.	726.08	402.10	305.88	286.40	267.63	113.87	284.60
n =	.	.	.	.	4	4	4	4	3	3	2
♀♂ $\bar{x}$ =	325.39	633.49	222.63	366.36	468.87	208.48	174.44	288.82	159.27	176.45	147.92
n =	7	7	7	7	14	13	13	13	12	12	11

[1] Year 1 = 1 March 1989 - 28 February 1990, Year 2 = 1 March 1990 - 28 February 1991, Year 3 = 1 March 1991 - 30 November 1992.

[2] Spring = 1 March - 31 May, Summer = 1 June - 31 August, Fall = 1 September - 30 November, Winter = 1 December - 28 February.

[3] Insufficient observations to determine home range, animal not alive during this season, or animal not part of telemetered population yet.

DISCUSSION

Thirty-three months of field work have been completed at RMA. Remaining tasks for the RMA deer project include 5 additional monthly ground counts (January, February, March, April, and May 1993). Most effort, however, will be directed at completion of data analysis and required course work at University of Wyoming. Formal management recommendations and protocols for monitoring RMA deer populations will be formulated at the completion of data analysis.

After 33 months of field work on RMA, 1 very important statistic has surfaced. Mule deer numbers have doubled over a period of 4 years on RMA. While the mule deer population has increased at a dramatic rate, the white-tailed deer population appears to be fluctuating. RMA is an island habitat and cannot sustain mule deer population growth that doubles every 4 years. The mule deer population must be controlled in the not too distant future. If artificial population regulation is not a feasible alternative, the potential exists for serious degradation of wildlife habitats and deer populations at Rocky Mountain Arsenal.

PROGRESS REPORT

FOR

THE WESTERN BURROWING OWL: INCREASING PRAIRIE DOG ABUNDANCE, FORAGING THEORY, AND NEST SITE FIDELITY

submitted by:

Linda S.W. Pezzolesi

January 1993

REPORT SUMMARY

The first field season of a 2-year study of burrowing owls at the Rocky Mountain Arsenal (RMA) began in March 1992 and continued through August 1992. The objectives of the study were:

1.) To determine burrowing owl response to prairie dog reintroductions.

2.) To assess the applicability of the sexually size dimorphic owl to foraging theory.

3.) To determine nest site fidelity by adults and return of juveniles.

OBJECTIVE 1:

A total of 40 burrows within the 663 hectares of RMA prairie dog towns were utilized by burrowing owls in 1992. All of these burrows, as well as those from 1990 and 1992, were entered into a Geographic Information Systems program.

OBJECTIVE 2:

Observations during dusk and after nightfall were completed. Foraging bout length, prey captures, time spent in the burrow, and behaviors were recorded. In addition, trapping of small mammals and insects were completed to determine prey availability. Crude protein and moisture content of small mammals and insects were also assessed.

OBJECTIVE 3:

Burrowing owls were first sighted on the RMA on 26 March 1992. In previous nesting seasons burrowing owls were first spotted on 2 April 1990 and 18 March 1991. A total of 29 adults and 57 juveniles were banded on the RMA in 1992. Ten return birds were also identified.

Introduction

The first field season of the study of burrowing owl (*Athene cunicularia*) foraging, nest site fidelity, and response to increasing prairie dog abundance began in March 1992. The following report summarizes the information gathered in March through August 1992. A second field season will take place in 1993. The objectives of the study were:

1.) To determine burrowing owl response to prairie dog reintroductions.

2.) To assess the applicability of the sexually size dimorphic owl to foraging theory.

3.) To determine nest site fidelity by adults and return of juveniles.

Each objective will be addressed in terms of data collected and completed analysis to date.

OBJECTIVE 1.

A total of 40 burrows were used by burrowing owls on the Rocky Mountain Arsenal (RMA), 26 of which (65%) yielded young. All burrows and active prairie dog towns, totaling 663 hectares, on the RMA were entered into the Geographic Information System program Erdas.

OBJECTIVE 2.

A total of 105 crepuscular/nocturnal observation hours were completed from 11 May through 16 July. Each observation began 1 hour before sunset and continued on for a total of four hours, and focused on 1 burrow randomly selected from a total of 10 crepuscular/nocturnal observation burrows. During observations, foraging bout length, prey captures, time spent in the burrow, and behaviors were recorded for both sexes. A total of 465 prey captures were returned to the nest (Table 2.1).

Table 2.1 Burrowing owl prey captures recorded during crepuscular/nocturnal observations in May, June, and July 1992, on the RMA, Colorado.

	Small mammal	Insect	Total
Male	32	182	214
Female	4	247	251
Total	36	429	465

Male foraging bouts ($\bar{x}$ = 257 seconds) were longer (P = 0.0001) than female ($\bar{x}$ = 193 seconds). Males took more ($P < 0.05$) small mammals (15%) than females (2%). Furthermore, foraging bouts when an owl returned with a small mammal ($\bar{x}$ = 327 seconds) were significantly longer (P = 0.0001) than those with an insect ($\bar{x}$ = 205 seconds).

Females tended to spend larger proportions of observations in the burrow ($\bar{x}$ = 0.45) than males ($\bar{x}$ = 0.25). Both sexes averaged approximately 45% prey capture success rate in total foraging bouts.

During nocturnal/crepuscular observations, behaviors were recorded every 5 minutes for both sexes (Table 2.2).

Table 2.2 Mean percentage of instantaneous behavioral events of 10 pairs of burrowing owls on the RMA, Colorado.

	Crepuscular/Nocturnal		Diurnal	
Behavior	Male	Female	Male	Female
Feeding	0.707	0.537	0.200	0.267
Locomotion	1.220	0.805	0.767	0.633
Resting	0.707	0.659	5.067	1.867
Comfort	1.000	0.001	1.267	1.533
Courtship	0.000	0.341	0.067	0.000
Alert	13.293	15.585	40.567	33.567
Agonistic	0.000	0.000	0.167	0.067
Out-of-sight	83.073	82.073	50.938	62.066

To determine value of small mammal and insect prey items to burrowing owls, crude protein and moisture content analysis was completed. Small mammals averaged 68% moisture content while insects averaged 62%. Digestible portions of small mammals had an average of 10.5% crude protein and insects had an average of 4.3% crude protein.

Small mammals and insects were trapped at each observation burrow. A total of 200 small mammals and 739 insects were captured over the course of three trapping sessions, the 1st through the 5th of May, June, and July.

Table 2.3 Captures of small mammals per 500 trap nights and insects per 700 trap nights at the RMA, Colorado.

	May	June	July	Total
Small Mammals	75	91	34	200
Insects	293	263	183	739

In order to more readily distinguish between male and female birds during observations, I will be perfecting a reflective leg band design and attachment technique. A reflective band will be placed on each female's right leg.

OBJECTIVE 3.

In 1992 adult burrowing owls were first spotted on the RMA on 26 March. Repeated searches by vehicle and on foot were completed to determine nesting sites of burrowing owl pairs. Specific nesting burrows were identified by signs of burrowing owl activity such as castings and fecal droppings.

A total of 29 adult (1990:N=34, 1991:N=50) and 57 juvenile (1990:N=61, 1991:N=114) burrowing owls were banded in 1992. The 26 successful nests (65% of total burrows used by burrowing owls) produced a total of 92 juveniles with an average of 3.5 emerged young per brood (1990:N=4.0, 1991:N=5.2). In 1992, the total return rate of burrowing owls of all banded 4.6% (1991:12.6%). Ten return birds were identified in the 1992 field season (Table 3.1). Of those returning birds, 80% were identified on the RMA in 1990 and 1991, 10% were first banded on the RMA in 1991, and the final 10% were banded in 1990, not found in 1991, and returned in 1992.

Table 3.1 Adult and juvenile burrowing owls which were banded on the RMA in 1990 or 1991 and returned to the RMA in 1992.

Age Banded	Sex	Return 1990?	Return 1991?	Orientation of burrow nests
adult	M	no	yes	- 1991 and 1992, same burrow
adult	M	yes	yes	- 1991 and 1992, same burrow - 1990, different prairie dog town
adult	M	yes	yes	- 1990-92, different prairie dog towns
adult	M	yes	yes	- 1990-92, different prairie dog towns
adult	M	yes	yes	- 1990-92, different prairie dog towns
adult	M	yes	yes	- 1990-92, different prairie dog towns
juvenile	M	yes	yes	- 1990-92, same prairie dog town
juvenile	M	yes	yes	- 1990-92, same prairie dog town - 1991 and 1992, same burrow
juvenile	F	yes	yes	- 1990-92, less than 20 meters apart
juvenile	F	yes	no	- 1990 and 1992, different prairie dog towns

In order to improve trapping success, I will be employing a second technician during brood emergence to assist with observations, allowing me the opportunity to dedicate my time to capturing juveniles and adults. In addition, I will also be constructing and utilizing a new trap design which has lead to increased trapping success of burrowing owls in California.

Fish Use of Structure at the Rocky Mountain Arsenal

ANNUAL REPORT

January 1993

Submitted by

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YEAR IN REVIEW:

Our focus this year was on making the echo integrator (our device for mapping and analyzing lake bottom characteristics) functional. After numerous setbacks, we were able to convince a commercial sonar manufacturer to customize a depth finder for our project, acquire a compass with suitable accuracy needed for mapping, and locate serial ports that could accurately interface with these two pieces of equipment. Extensive programming has allowed us to develop software to acquire depth and vegetation indices for any point on the lake, having only entered initial coordinates. These data will provide the foundation for depth, vegetation, and diversity index maps essential for our analysis of habitat preference by resident northern pike and largemouth bass.

Our 24 hour tracking sessions continued throughout 1992 providing over 900 additional fixes. Weekly tracks were also conducted during the summer field season in hopes of correlating our 24 hour data to much of the existing literature. Behavior patterns observed by the fish were similar for those observed in 1991. Colder months drove the fish into warmer deeper waters, while the warming and cooling waters of spring and fall allowed fish to explore the entire reservoir. In the summer, largemouth bass were closely associated with the shoreline, favoring areas where anglers had trampled much of the aquatic macrophytes, creating ideal foraging habitat. The northern pike (as they did last year) were concentrated in the arm of Ladora. Water coming in from the bottom of Lower Derby makes this the coldest water in Ladora despite being only 0.5 meters deep. Although the habitat appears marginal here, cool water seems to attract northern pike.

We presented some of our 1991 results at the western division AFS meeting in Fort Collins relating to the effects of water level drawdown on largemouth bass and northern pike at the Rocky Mountain Arsenal. We found that when water levels were dropped one meter in Lower Derby, fish moved more per hour and exhibited larger 24 hour "home ranges" than they did during either pre or post drawdown conditions. Ladora was used as our control lake and fish movement here remained unchanged over the course of the seven month study.

Attrition of tagged fish and tag failure has continued through 1992. When fish perished, the tags could often be recovered. Unfortunately, the fish were usually fine, while the transmitter itself would fail after emitting awkward sounding tones for a month or two. Although the manufacturer (Sonotronics - Tucson,AZ) assured us that our tags had a theoretical battery life of 5 years, the mechanical life of the transmitters is apparently much less :)

FALL QUARTER HIGHLIGHTS:

It works. Our much maligned echo integrator came off injured reserve this quarter and became a fully functional unit. Depth data was collected on the Arsenal and Horsetooth Reservoir. This will allow us to spend the winter quarter analyzing bottom contours and fine tuning our diversity indices. Habitat preferences of fish will also be investigated with the aid of a geographic information system (GIS). Since GIS's are generally extremely expensive, we had envisioned down-loading our data onto a unix workstation running the ARC/INFO GIS software package. This may no longer be necessary as Thinkspace (John Wiley, New York) has developed a GIS with support from the Canadian government called MAPII that can run on a Macintosh platform and perform all the analysis we need. Acquiring this package will allow us to analyze our data in the field, without the problems associated with data conversion and transfer.

ECHO INTEGRATOR STATUS:

The two bugs discussed in the previous report have been resolved, and transects have been run successfully on the Rocky Mountain Arsenal. This x,y,z formatted data will be entered into a GIS package to generate maps of the lake bottom.

As expected, some of our diversity indices performed better than others, making certain refinements necessary. These refinements will include evaluating residuals instead of correlation coefficients, randomizing transects prior to implementing the theory of runs, and interpreting the Fourier transform index in an unorthodox fashion.

TRACKING:

A total of three sonic tags were recovered this year. One was returned to Sonotronics for repair, while the others were implanted in a northern pike in Lower Derby and a largemouth bass in Lake Ladora (vital statistics in Appendix 1). This was the first time we implanted tags in fish in the fall during cooling rather than warming water temperatures. It is hoped that the subjects heal before very cold temperatures are realized. As of our December track, the two individuals seemed to be as active as their tagged brethren, indicating that the surgery two months prior was successful.

Rich Velin, Dan Stubbs, and Dick Kaufmann assisted with our 24 hour tracks this quarter. BEMA regulations went into effect on October 15, but unseasonably warm weather in September and October seemed to have kept the eagles from showing up at the Arsenal until late November. The absence of eagles allowed us to perform a regular 24 hour track in November. Our abbreviated tracking scheme used last winter was implemented on our December track.

Although tag failure was documented among some of our fish, the remainder were easily located in the thinning vegetation. As expected, cooling water temperatures and thinning vegetation allowed both pike and bass to explore more of each lake.

FUTURE PLANS:

Our diversity indices will be refined to address the shortcomings that arose while evaluating both theoretical and real world bottom transects. Acquisition of depth traces will resume immediately after ice off, taking advantage of reduced vegetation levels. Other lentic systems will be considered for mapping as well, to obtain a full spectrum of bottom contours. This will enhance the evaluation of diversity index performance.

Twenty-four hour tracks will continue through the winter quarter, following the abbreviated tracking schedule used in January and February of last year. Cold weather has already created a substantial ice lid on both lakes that was at least 7 cm thick during our last track. This should allow us to continue walking out on the lakes and drilling holes in the ice to assess fish location through February.

We intend to submit an abstract to the Fourth National U.S. Fish and Wildlife Service GIS Workshop in Lafayette, Louisiana. This paper will evaluate vegetation preferences of northern pike and largemouth bass in lakes Ladora and Lower Derby using a GIS. If accepted, we will present the data on May 3-6, 1993.

APPENDIX

Appendix I: Included is an updated list of the fish we have PIT tagged in the Arsenal lakes, including their length, weight, PIT tag number, sonic tag number, and method of take.

LADORA BASS:

Length (mm)	Weight (Kg)	PIT tag number	Captured	Method	tag ID
470	1.73	7F7D172D38	4/10/91	NET	284
476	1.59	7F7D172842	4/10/91	NET	626
310	0.43	7F7D134466	5/01/91	LINE	
320	0.51	7F7D1A3502	5/01/91	LINE	
276	0.34	7F7D126D5D	5/01/91	LINE	
330	0.63	7F7D1A3008	5/01/91	LINE	
415	1.25	7F7D13023D	5/01/91	LINE	365
380	0.94	7F7D1A2D33	5/01/91	LINE	374
290	0.34	7F7D13411A	5/01/91	LINE	
328	0.57	7F7D137A59	5/01/91	LINE	
286	0.34	7F7D126D13	5/01/91	LINE	
450	1.25	7F7D1A4D2A	5/16/91	LINE	347
290	0.40	7F7D222A43	5/16/91	LINE	
465	1.76		6/11/91	SHOCK	
465	1.88		6/11/91	SHOCK	
412	1.08		6/11/91	SHOCK	
412	1.33	7F7D171C4E	5/05/92	LINE	258
463	1.53	7F7D222C2F	5/05/92	LINE	276
502	2.13	7F7D133C7D	5/05/92	LINE	348
380	1.02	7F7D183079	5/05/92	LINE	285
406	1.19	7F7D1A4B77	10/12/92	LINE	87

LOWER DERBY BASS:

Length (mm)	Weight (Kg)	PIT tag number	Captured	Method	tag ID
334	0.63	7F7D170B18	4/24/91	NET	
368	0.91	7F7D1A2F4B	4/24/91	NET	
342	0.77	7F7D1A4B14	4/24/91	NET	
363	0.80	7F7D222D5D	4/24/91	NET	
466	2.07	7F7D140C4A	4/24/91	NET	275
355	0.71	7F7D164F57	4/24/91	NET	
345	0.77	7F7D1A466F	4/24/91	NET	
368	0.97	7F7D1E463A	4/24/91	NET	
320	0.57	7F7D1E5A0B	4/24/91	NET	
333	0.57		5/10/91	NET	
486	2.39	7F7D1A333A	5/16/91	SHOCK	96
456	1.82	7F7D1A4A1E	5/16/91	SHOCK	87
485	2.36	7F7D0D092F	5/16/91	SHOCK	2227
402	1.00	7F7D13345E	5/16/91	SHOCK	2236
362	0.88	7F7D134868	5/16/91	SHOCK	
341	0.80	7F7D134D2F	5/16/91	SHOCK	
358	0.86	7F7D1A4867	5/16/91	SHOCK	
188	0.11		5/16/91		
336	0.63		5/16/91		
324	0.63		5/16/91		
324	0.57		5/16/91		
197	0.14		5/16/91		
176	0.11		5/16/91		

187	0.11		5/16/91		
183	0.09		5/16/91		
430	1.47	7F7D1A3527	4/24/92	LINE	357
410	1.19	7F7D140A7B	5/05/92	LINE	366
400	1.05	7F7D1A466F	5/05/92	LINE	

LADORA PIKE:

Length (mm)	Weight (Kg)	PIT tag number	Captured	Method	tag ID
650	1.88	7F7D165D25	4/10/91	NET	338
800	2.96	7F7D141D34	4/10/91	NET	725
887	4.28	7F7D1A3358	4/10/91	NET	464
802	2.98	7F7D12657D	4/10/91	NET	
735	2.50	7F7D1A370A	4/10/91	NET	545
490	0.82	7F7D1A465F	5/01/91	LINE	
512	0.91	7F7D1A4B73	5/01/91	LINE	
547	1.08	7F7D131541	5/01/91	LINE	
552	1.20	7F7D141D36	5/01/91	LINE	446
724	2.38	7F7D1D4A1E	3/19/92	TRAP	294
715	2.49	7F7D1D3F74	3/19/92	TRAP	267

LOWER DERBY PIKE:

Length (mm)	Weight (Kg)	PIT tag number	Captured	Method	tag ID
660	1.54	7F7D143048	4/24/91	NET	356
630	1.56	7F7D161E79	4/24/91	NET	248
584	1.42	7F7D180E05	4/24/91	NET	
591	1.25	7F7D1D6B74	4/24/91	NET	
656	1.59	7F7D1A494F	4/24/91	NET	455
710	2.27	7F7D134B01	4/24/91	NET	383
577	1.25	7F7D1A2C2F	4/24/91	NET	
800	3.38	7F7D1H4772	5/10/91	NET	293
708	2.16	7F7D22677D	5/10/91	NET	
734	2.42	7F7D1A3053	5/10/91	NET	
576	1.22	7F7D1A4A57	5/10/91	NET	
760	2.27	7F7D22293A	5/10/91	LINE	
612	1.25	7F7D12567A	5/10/91	NET	
720	2.16	7F7D170F75	5/10/91	NET	
732	2.64	7F7D1A313D	5/05/92	NET	249
732	2.10	7F7D1A2F26	5/05/92	NET	339
709	1.70	7F7D1A4660	5/05/92	NET	
559	1.36	7F7D164B10	10/12/92	LINE	339

SUCCESSIONAL CHANGES AND WATER QUALITY IN ARTIFICIAL WETLANDS AT THE ROCKY MOUNTAIN ARSENAL

A Progress Report Submitted to the U.S. Fish and Wildlife Service

Rocky Mountain Arsenal, Commerce City, CO

October 15, 1992

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INTRODUCTION

The U.S. Army and U.S. Fish and Wildlife Service created five wetlands on Rocky Mountain Arsenal (RMA) during the summer and fall of 1991. These wetlands were developed primarily to supply habitat in the event that previously existing RMA wetlands required draining for management purposes. The purpose of this project was to study water quality trends, contaminant assimilative capacity, and aquatic macroinvertebrate community development of these wetlands. In this study, contaminant assimilation was defined as the ability of a wetland to reduce contaminant bioavailability and toxicity to aquatic organisms. Specific objectives of this research were:

* examination of temporal changes in water quality parameters and assimilative capacity as the wetlands become established;
* identification of potential pathways for contaminant transfer within the wetlands;
* determination of the value of single species bioassays as indicators of ecological integrity of these wetlands;
* examination of colonization of wetlands by aquatic macroinvertebrates over time.

Expected Benefits

Toxicity tests on survival and reproduction of *Ceriodaphnia dubia* exposed to zinc and wetland water will be used to determine which wetland characteristics are responsible for contaminant assimilation. Some biological and physical characteristics which may increase or decrease assimilative capabilities of the wetlands include water chemistry, macrophyte biomass, water depth, and suspended sediments levels. Information gained from these tests may be utilized in wetland management.

Toxicity tests and macroinvertebrate samples were employed to monitor the condition of wetlands at RMA. Comparison of laboratory and field data will allow us to determine whether the C. dubia bioassay, an inexpensive method for water quality assessment, is an acceptable measure which may be extrapolated to other levels of aquatic life within the wetlands at RMA. Finally, information on macroinvertebrate communities colonizing wetlands at RMA will contribute knowledge towards RMA wetland management, as these organisms are an important food source to higher trophic levels.

This report summarizes field and laboratory work performed from August 1991 through September 1992.

SITE DESCRIPTION

The five wetland basins were constructed in the southeast corner of RMA (Fig. 1). Wetlands RMA3, RMA4, and RMA5 were natural basins which required no alterations other than the addition of water. The volume of RMA2 was increased slightly by excavating the basin and heightening the road which serves as a dike. The main basin of wetland RMA1 was layered with bentonite to maintain a permanent pool. This will provide year-round habitat for aquatic life.

The primary source of water for these wetlands is Highline Canal, which originates from the South Platte River, south of Denver. Filling the basins with water was dependent on water rights appropriations, and natural precipitation. The sequence of filling of the wetland basins in 1991 was staggered from late July through late October. Due to differences in soil composition, water retention of the wetlands varied. For example, RMA2 was filled 5 August 1991 and lost all of its surface water by late September 1991. RMA4 and RMA3 were filled

29 July and 15 August 1991, respectively, and held water throughout the winter months and into the spring. RMA3 was dry by early May 1992. RMA4 was replenished by Highline Canal in late May 1992 and never dried. RMA5 was filled 24 August 1991 but was dry by mid-October 1991. RMA1 was partially filled 26 September 1991, and held water through the spring of 1992, when refilling began.

Ladora Lake (RMAL), a previously existing wetland at RMA, serves as a reference site for water quality trends in this study. As with the artificial wetlands, Highline Canal is the primary source for RMAL, via Upper and Lower Derby Lakes. Observations indicate that water quality trends in the created wetlands (RMA3 and RMA4) resembles those of RMAL after two to three weeks residence time (Figures 2 and 3).

METHODS

Macroinvertebrate Sampling

Aquatic macroinvertebrates were collected from several microhabitats (i.e. open water, shoreline) using a D-frame net (1-mm mesh), preserved in 60% ethanol, and transported to the laboratory (Colorado State University, Ft. Collins, CO). These organisms are currently being sorted and identified to the lowest practical taxonomic level. Macroinvertebrate parameters analyzed will include species richness and relative abundance from net sweeps. Relationships between vegetation and macroinvertebrate functional groups will also be analyzed.

Toxicity Testing

Experiments measuring reproduction and mortality of C. dubia were conducted to determine relative assimilative capacity of wetlands RMA3, RMA4, and RMAL. Water collected from each wetland was spiked with 0.0 (control), 50.0, 100.0, and 200.0 ug/L zinc. Tests were performed quarterly to determine seasonal and temporal effects on toxicity. Experiments were carried out in accordance with EPA 3-brood chronic toxicity testing procedures (U.S. EPA 1989). On each collecting date, twelve liters of water were collected from each wetland and immediately placed on ice. In the laboratory, water was filtered through a plankton net to remove large particulate matter and indigenous organisms. Water collected from wetlands RMA3, RMA4, and RMAL served as control water and diluent.

Individual C. dubia were run for each wetland (with ten replicates per treatment) were placed into 30 ml containers and exposed to the five test concentrations and a moderately hard reference water (reconstituted water with hardness≈65 and alkalinity≈65 mg/L $CaCO_3$). The mean number of neonates produced per female was analyzed using General Linear Models and Tukeys on: 1) wetlands vs. dilution and 2) all combinations of dilutions within each wetland.

Water Quality

Routine water quality data was collected weekly or bi-weekly in 1991 from mid-August through early December, and in 1992 from mid-March through the present (September). Field measurements included water temperature, dissolved oxygen (using a Y.S.I. model 51B dissolved oxygen meter), depth, and secchi depth. One liter of water was collected from each wetland and transferred to the laboratory for measurement of pH, alkalinity, hardness, and conductivity. When collecting water for toxicity tests additional water was taken for analysis of total suspended and total dissolved solids, dissolved organic carbon, and zinc.

Suspended and dissolved solids were measured in the laboratory following EPA's (1983) gravimetric procedures. Zinc concentrations were determined using flame atomic absorption spectrophotometry at the Colorado Division of Wildlife Research laboratory in Ft. Collins. Samples for dissolved organic carbon determination were filtered (0.45μm) and acidified and analyzed by Analytical Technology Inc. (Ft. Collins).

During rain events water was collected from Havana Ditch (on and off RMA property) and Havana Street ($\approx$1Km south of RMA property-Fig. 1.a.). Havana Ditch, a cement canal which collects urban/industrial runoff from the south of RMA, enters the arsenal and empties into Havana Pond. This water was sampled for basic water quality parameters and zinc to determine the potential for metal contamination of RMA during storm events.

RESULTS

Water Quality

Water quality and physical data (pH, alkalinity, hardness, conductivity, dissolved oxygen, total depth, and secchi depth) collected from all RMA wetlands and Lake Ladora (RMAL) are provided in Appendix I. Seasonal changes in selected water quality variables at RMA3, RMA4, and RMAL during 1991 and 1992 are shown in Figs. 2 and 3.

During 1991, pH was generally higher in RMAL than the two artificial wetlands (Fig. 2). The only exception to this pattern occurred during late summer and early fall, immediately after wetlands were filled, when pH in RMA3 was greatly elevated. Water hardness and alkalinity in RMA3, RMA4, and RMAL were similar initially, but increased in RMA3 in the fall. Conductivity was generally lowest in RMA4 and highest in RMAL. The seasonal increase in conductivity from September to December at RMA3 paralleled increased hardness and alkalinity.

Water quality parameters measured at RMA3, RMA4, and RMAL during 1992 varied seasonally and among wetlands (Fig. 3). Much of this variation resulted from seasonal changes in depth, particularly at RMA3 (Appendix 1). Water levels in this wetland were low during the early spring, and the system was completely dry for a two-week period in May. Reduced water levels resulted in greatly elevated hardness, alkalinity, and conductivity at RMA3 during early spring. pH in RMA4 was also elevated during the period from mid-May to early-June and again in late summer. Elevated pH in this system was paralleled by greatly increased dissolved oxygen levels during these same periods (Appendix 1).

Chronic Toxicity Tests

Results of chronic toxicity tests conducted with *Ceriodaphnia dubia* exposed to Zn-spiked water collected from RMA3, RMA4, and RMAL are shown in Fig. 4. Water quality parameters (pH, alkalinity, hardness, conductivity, depth, total suspended solids, secchi depths, and dissolved organic carbon) at these wetlands when water was collected for toxicity tests are shown in Table 1.

The mean number of neonates per female ranged from 22-34 in controls and from 22-29 in moderately hard reconstituted (MH) water. Reproduction in RMAL controls was significantly lower than RMA3 or RMA4 controls in February and July experiments. In contrast, control reproduction in RMA4 was significantly lower than RMA3 and RMAL in April.

The number of neonates in MH controls was similar for each test, indicating good replicability among experiments. However, on several occasions, Ceriodaphnia reproduction in control wetland water was significantly greater than reproduction in MH water.

a. December 1991

The effects of Zn on Ceriodaphnia reproduction varied significantly among seasons and among wetlands (Fig. 4, Table 2). In December, there were no effects of Zn on Ceriodaphnia reproduction in RMA3 water, even at 200 µg/L. In contrast, 100% mortality was observed in the 100 µg/L and 200 µg/L treatments from RMAL and RMA4, respectively. Water hardness and alkalinity in RMA3 were 1.7-1.9X and 1.9-2.2X greater than either of the other systems. In addition, total and secchi depths of RMA3 were less than half that of RMA4.

b. February 1992

Ceriodaphnia reproduction was slightly greater in 0, 50, and 100µg/L treatments from RMA3 than RMA4 in February. RMA3 produced significantly more neonates than

RMA4 at 200$\mu g/L$. In contrast, reproduction in all RMAL treatments (except the MH control) was significantly less than either RMA3 and RMA4 and all organisms in the 200 $\mu g/L$ treatment died. Most water quality parameters in RMA3 and RMA4 were similar during February. Exceptions were depth and dissolved organic carbon (DOC). Depth was considerably lower in RMA3 (0.06 m) than in RMA4 (0.61 m) while DOC of RMA4 was nearly twice that of RMA3. Conductivity, pH, and water hardness were higher at RMAL than RMA3 or RMA4.

c. April 1992

In April experiments, Zn had little, if any impact on organisms in RMA3 and RMA4 exposures, whereas all organisms in RMAL at the 200 $\mu g/L$ Zn treatment died. In contrast to previous experiments, however, Ceriodaphnia reproduction in the 100 $\mu g/L$ treatment from RMAL was similar to that in RMA3 and significantly greater than RMA4. Alkalinity, hardness, conductivity, and total suspended solids were greatly elevated at RMA3 during April due to reduced water levels. DOC levels were similar between RMA3 and RMA4 but much lower at RMAL. TSS in RMA3 were 5X and 20X that of RMA4 and RMAL respectively, while RMA3 depth was 25% that of RMA4.

d. July 1992

Ceriodaphnia reproduction was not affected by Zn-spiked water from RMA4 during the July experiments. Reproduction of organisms in RMAL water was significantly lower than in RMA3 and RMA4 in control, 50, and 100 $\mu g/L$ treatments. All organisms died in the 200 $\mu g/L$ treatments from RMAL and RMA3. Most water quality parameters were similar between RMA3 and RMA4. An important exception was TSS which was much greater at RMA4. Alkalinity, hardness, TSS, and

DOC were considerably lower at RMAL than at the other wetlands.

Benthic Macroinvertebrates

Aquatic macroinvertebrate samples were collected every two weeks from RMA3, RMA4, and RMAL. These samples are currently being sorted and identified. Preliminary results indicate that aquatic macroinvertebrates become established within two weeks following filling of the wetlands. When wetlands went dry (RMA2, RMA3, RMA5), macroinvertebrates re-established within a week. In RMA4 (relatively permanent), a more diverse macroinvertebrate community has developed. These results will be presented in future reports.

DISCUSSION

Water Quality

Results of this research indicate that water quality of wetlands created at RMA and the ability of these systems to assimilate contaminants (e.g. Zn) varied seasonally and among wetlands. The same source water was used to fill each wetland (Highline Canal). Therefore some of the chemical and physical differences among wetlands most likely resulted from initial differences in soil, vegetation, and hydrologic characteristics. Comparison of wetlands is complicated by the fact that several of the systems (RMA1, RMA2, RMA3, RMA5) dried up in spring and late fall. Despite these complications, comparison of mean values of physical and chemical characteristics from the wetlands to RMAL indicates that in many aspects, wetlands were similar to this natural system.

On several occasions levels of dissolved oxygen (D.O.) in wetlands reached critical levels. For example, levels at RMA1 (24 June), RMA2 (16 June), RMA3 (21 April, 16 June), and RMA5 (24 June, 30 June, 14 July) were below 3.0 mg/L. The cause of reductions in D.O. levels is most likely a result of high decomposition rates of recently-submerged terrestrial vegetation. This combined with initially low productivity could be the primary causes of low D.O. conditions. It is interesting to note that low D.O. was observed in RMA4 only on the first sampling occasion in 1991, shortly after the wetlands were filled. D.O. levels in RMA4 exceeded 12.0 mg/L on several occasions and resulted in significant increases in pH.

Effects of RMA Wetlands Water on Ceriodaphnia Reproduction

Results of these experiments demonstrated that water collected from RMAL, RMA3, and RMA4 were of high quality and quite adequate for Ceriodaphnia.

Reproduction in controls (e.g. 100% wetland) always exceeded standard U.S. EPA guidelines for conducting chronic toxicity tests. On most occasions, reproduction was better in control water than in MH water. These results support previous findings (Quarterly Report No. 1) and suggest that wetland water contained certain constituents lacking in MH water. Based on these results, we conclude that surface waters in RMA wetlands are of high quality and are sufficient to support healthy fish and wildlife populations.

Assimilative Capacity of RMA Wetlands

The primary purpose of the *Ceriodaphnia* experiments was to test the assimilative capacity of artificial wetlands at RMA for Zn. Assimilative capacity refers to the ability of an ecosystem to degrade or detoxify a contaminant. This process occurs by a variety of physical (adsorption to particulates), chemical (binding to dissolved organic carbon, reduced contaminant availability), and biological mechanisms (uptake and degradation by microbial communities and plants).

With construction of the new airport northeast of Denver, it is expected that nonpoint source pollution entering surface waters at RMA will increase. Because these surface waters are the primary source of water for RMA wetlands, information about the assimilative capacity of these systems is important. The heavy metal Zn was chosen as a reference toxicant in these experiments because recent analysis of metals in surface waters indicated high levels of this contaminant.

The effects of water quality on toxicity of contaminants are well documented (Rand and Petrocelli, 1979). In particular, increased water hardness, alkalinity, dissolved organic carbon, and total suspended solids have been shown to reduce toxicity of heavy metals. Secchi depth may also prove useful as an indicator of a combination of assimilative qualities, including suspended solids and productivity (i.e. macro and phytoplankton). Because these parameters varied among wetlands at RMA, it was expected that effects of contaminants will also vary among these systems.

One potential physical factor which may account for differences among wetlands is water body/substrate ratio. Throughout most of these tests, this ratio was considerably lower in RMA3 than in RMA4 (Appendix 1., see depth). The water body/substrate ratio will have a strong influence on substrate:water interaction, mixing, and productivity. This factor will be examined in future reports.

Differences in water quality among wetlands and seasons greatly influenced effects of Zn on reproduction of Ceriodaphnia. We hypothesize that these differences were related to the capacity of wetlands to assimilate and/or detoxify Zn. In general toxic effects of Zn were greater on organisms in RMAL water than either of the artificial wetlands. Mortality was observed at the 200 ug/L Zn treatment in RMAL water in all experiments. Greater toxicity of Zn to organisms in RMAL water most likely resulted from generally lower hardness, alkalinity, TSS, and DOC. These results suggest that the assimilative capacity of RMAL will be less than that of the other wetlands and that levels of Zn exceeding 100 ug/L in this system will likely result in impaired biological integrity.

Comparison of results from RMA3 and RMA4 indicate that the assimilative capacity of these systems varied with season. Reduced Zn toxicity in RMA3 compared to RMA4 in December may have resulted from greater hardness and alkalinity of RMA3. Unfortunately, TSS and DOC were not measured in December and therefore the contribution of these parameters to Zn bioavailability was not known. Effects of Zn on reproduction were similar between RMA3 and RMA4 during February at all concentrations with the exception of 200μg/L. This may indicate higher assimilative capabilities in RMA3. Most water quality parameters, except for DOC (which was elevated at RMA4) were similar between these wetlands. This suggests that DOC alone does not drive contaminant assimilation.

Effects of Zn-spiked RMA3 and RMA4 water on Ceriodaphnia in April were diverse. Water hardness and alkalinity were much higher at RMA3 during this period, primarily due to reduced water levels in the wetland. All wetlands showed apparent assimilation (RMA3 and RMA4 through 200μg/L, RMAL through 100μg/L); however, total numbers for RMA4 were significantly lower than both RMA3 and RMAL. C. dubia exposed to RMA4 water produced neonates at 200μg/L, whereas the RMAL treatments showed 100% mortality at this concentration. This suggests water quality conditions in RMA4 which suppressed total production did not decrease assimilative capabilities. These results indicate the complex interactions between water quality parameters and contaminants.

RMA4 had significantly higher production than the other wetlands during the July test. This is the only test in which RMA3 had a similar water body/substrate ratio as RMA4. In addition, macrophyte and phytoplankton production were considerably higher in RMA4 (personal observation). These factors resulted in increased turbidity, TSS, and DOC in RMA4 compared to RMA3 (Table 1.).

Seasonal differences in Zn toxicity were most likely related to differences in water quality. Because of seasonal variation in hardness, alkalinity, TSS, and DOC, we suggest that the assimilative capacity of RMA wetlands will also change over time. For example, levels of Zn that showed no adverse effects during December, February, and April at RMA3 resulted in 100% mortality in July.

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Table 1. Chemical and physical water parameters of artificial wetlands (RMA3 and RMA4) and Ladora Lake (RMAL) during four chronic toxicity tests.

Test	Wetland	pH	(mg/L CaCO3) Alkalinity	Hardness	(umho) Cond.	(M) Total Depth	(M) Secchi Depth	(mg/L) T.S.S.	(mg/L) D.O.C.
Dec 91	RMA3	7.9	336	316	750	0.3	0.19	-	-
	RMA4	7.8	178	165	436	0.64	0.40	-	-
	RMAL	8.3	155	186	674	0.82	btm	-	-
Feb 92	RMA3	7.5	134	118	312	0.06	btm	5.6	12
	RMA4	7.0	125	120	368	0.61	btm	3.1	23
	RMAL	8.6	154	198	678	1.11	0.72	5.9	6
Apr 92	RMA3	8.7	400	500	1180	0.09	btm	59.5	36
	RMA4	7.9	148	127	478	0.46	btm	12.2	32
	RMAL	8.5	160	204	713	0.8	btm	3.0	7.1
Jul 92	RMA3	8.3	222	244	660	0.67	0.57	5.8	18
	RMA4	8.2	200	188	549	0.81	0.39	21.4	23.5
	RMAL	8.1	143	154	543	0.98	btm	2.7	6.3

Table 2. Results of Tukeys SNK test for comparison of means between and within wetlands for the <u>Ceriodaphnia dubia</u> chronic toxicity tests.

<u>Between Wetlands</u>

		concentrations				
test	wetlands	control	50	100	200	MH
Dec 1991	3/4	.5869	.0771	.0627	-	.8097
	3/L	.7937	.0591	.3535	-	.0881
	4/L	.4089	.9608	.9283	-	.0580
Feb 1992	3/4	.1554	.0004	.5620	.0001	.1238
	3/L	.0001	.0001	.0001	-	.7458
	4/L	.0001	.0001	.0001	-	.2387
Apr 1992	3/4	.0001	.0001	.0001	.0001	.0274
	3/L	.5337	.0069	.8864	-	.2953
	4/L	.0001	.0001	.0001	-	.2268
Jul 1992	3/4	.5136	.7438	.0394	-	.3024
	3/L	.0001	.0001	.0006	-	.5468
	4/L	.0001	.0005	.0001	-	.1038

<u>Within Wetlands</u>

test	wetland	C-50	C-100	C-200	50-100	50-200	100-200	MH-C	MH-50	MH-100	MH-200
Dec 1991	RMA3	.9890	.4216	.7673	.4020	.7504	.5964	.4294	.4089	.9726	.6109
	RMA4	.2087	.0291	-	.4362	-	-	.6253	.4310	.0959	-
	RMAL	.0340	-	-	.6630	-	-	.5250	.0071	.0948	-
Feb 1992	RMA3	.7598	.0393	.0604	.0792	.1163	.8466	.0001	.0001	.0002	.0001
	RMA4	.0137	.2387	.0001	.1775	.0001	.0001	.0001	.0007	.0001	.0637
	RMAL	.1719	.2852	-	.7813	-	-	.2292	.0041	.0134	-
Apr 1992	RMA3	.0349	.0176	.0129	.7371	.6514	.9101	.0001	.0012	.0048	.0068
	RMA4	.4195	.9195	.3427	.3640	.8698	.2953	.3640	.9195	.3133	.9477
	RMAL	.2268	.0356	-	.0011	-	-	.0001	.0001	.0001	-
Jul 1992	RMA3	.5136	.2539	-	.0743	-	-	.0001	.0001	.0001	-
	RMA4	.7438	.7001	.4145	.4885	.6241	.2492	.0001	.0001	.0001	.0001
	RMAL	.0193	.3427	-	.1516	-	-	.7620	.0065	.1980	-

Figure Legends

Figure 1. Map of wetlands at Rocky Mountain Arsenal, Commerce City, CO.

Figure 2. Water quality trends (pH, alkalinity, hardness, conductivity) at RMA3, RMA4, and RMAL. Data are weekly values collected from 16 August to 5 December, 1991.

Figure 3. Water quality trends (pH, alkalinity, hardness, conductivity) at RMA3, RMA4, and RMAL. Data are weekly values collected from 17 March to 5 October, 1992.

Figure 4. Results of chronic toxicity tests conducted with Ceriodaphnia dubia in December 1991, February 1992, April 1992, and July 1992. Organisms were exposed to Zn-spiked water collected from RMA3, RMA4, and RMAL. Values represent mean number of neonates per female. MH=moderately hard reconstituted water (alkalinity=65 mg/L; hardness=90 mg/L). C=control.

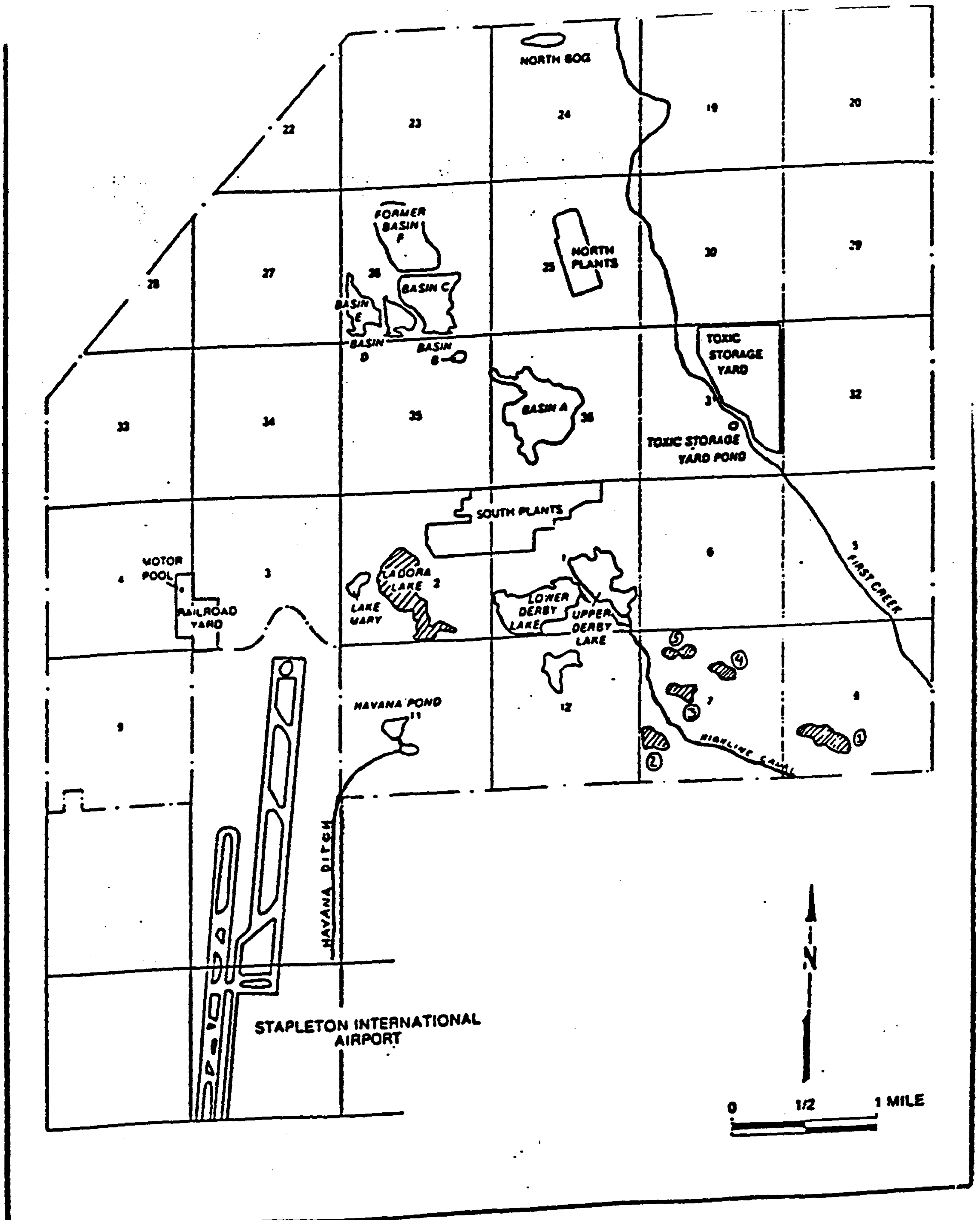


Fig 1.a. Rocky Mountain Arsenal, Commerce City, CO. [hatched symbol] -Indicates wetlands involved with this study (modified from ESE, 1988).

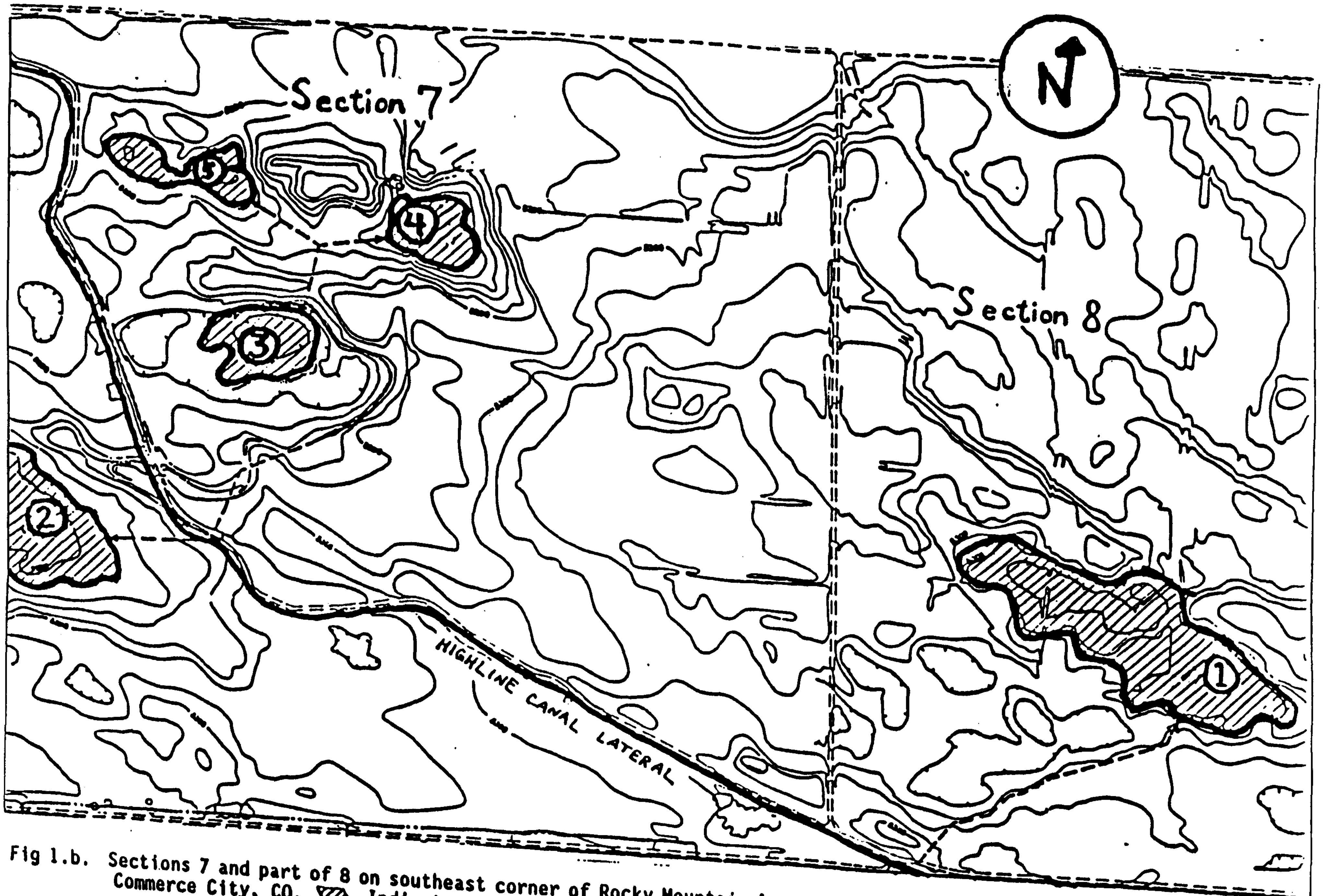


Fig 1.b. Sections 7 and part of 8 on southeast corner of Rocky Mountain Arsenal, Commerce City, CO. [hatched symbol]-Indicates wetlands involved with this study.

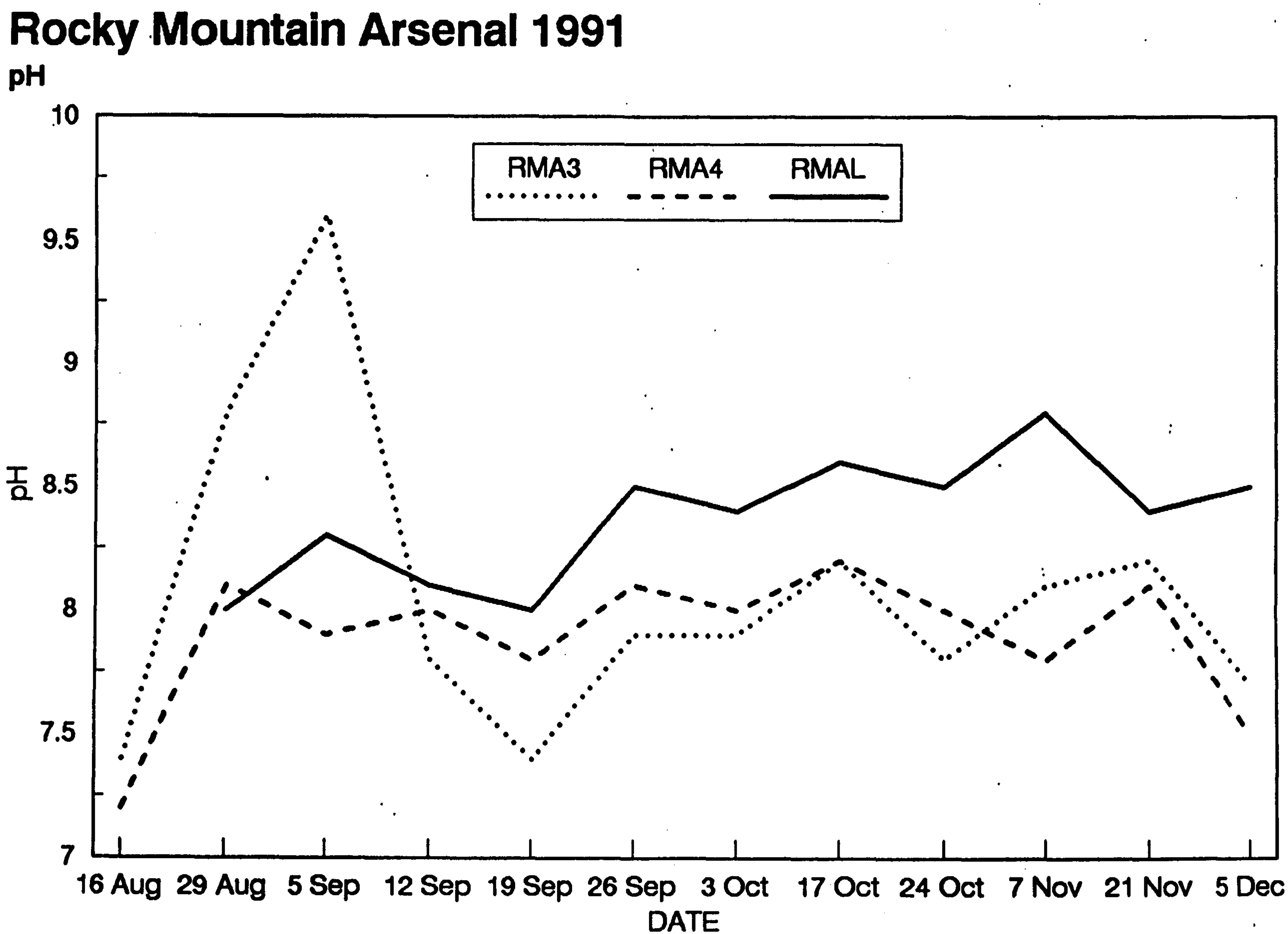
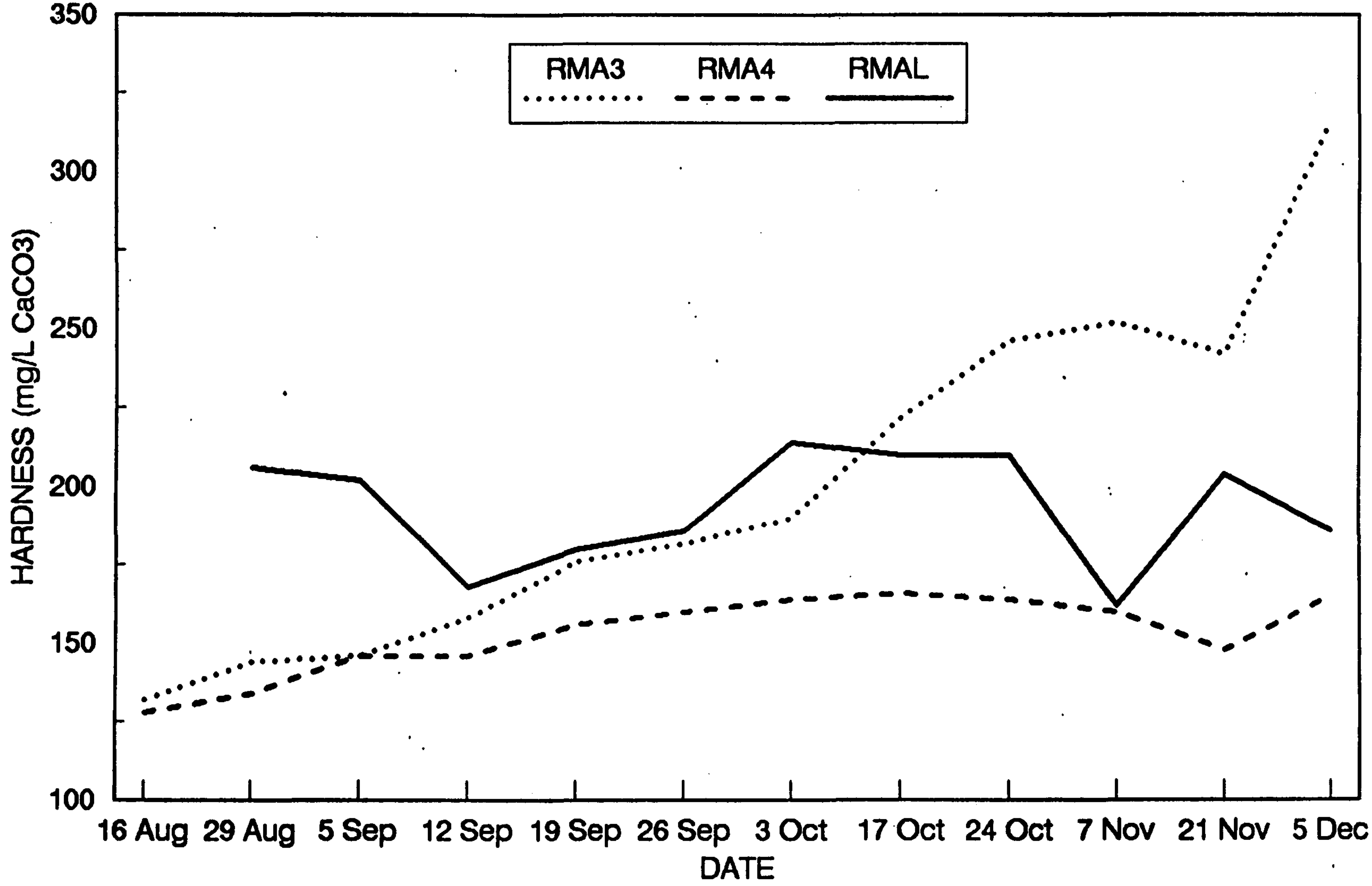

Rocky Mountain Arsenal 1991
pH
10
9.5
9
8.5
8
7.5
7
pH
RMA3
RMA4
RMAL
16 Aug
29 Aug
5 Sep
12 Sep
19 Sep
26 Sep
3 Oct
17 Oct
24 Oct
7 Nov
21 Nov
5 Dec
DATE

Figure 2

Figure 2

Rocky Mountain Arsenal 1991

Hardness



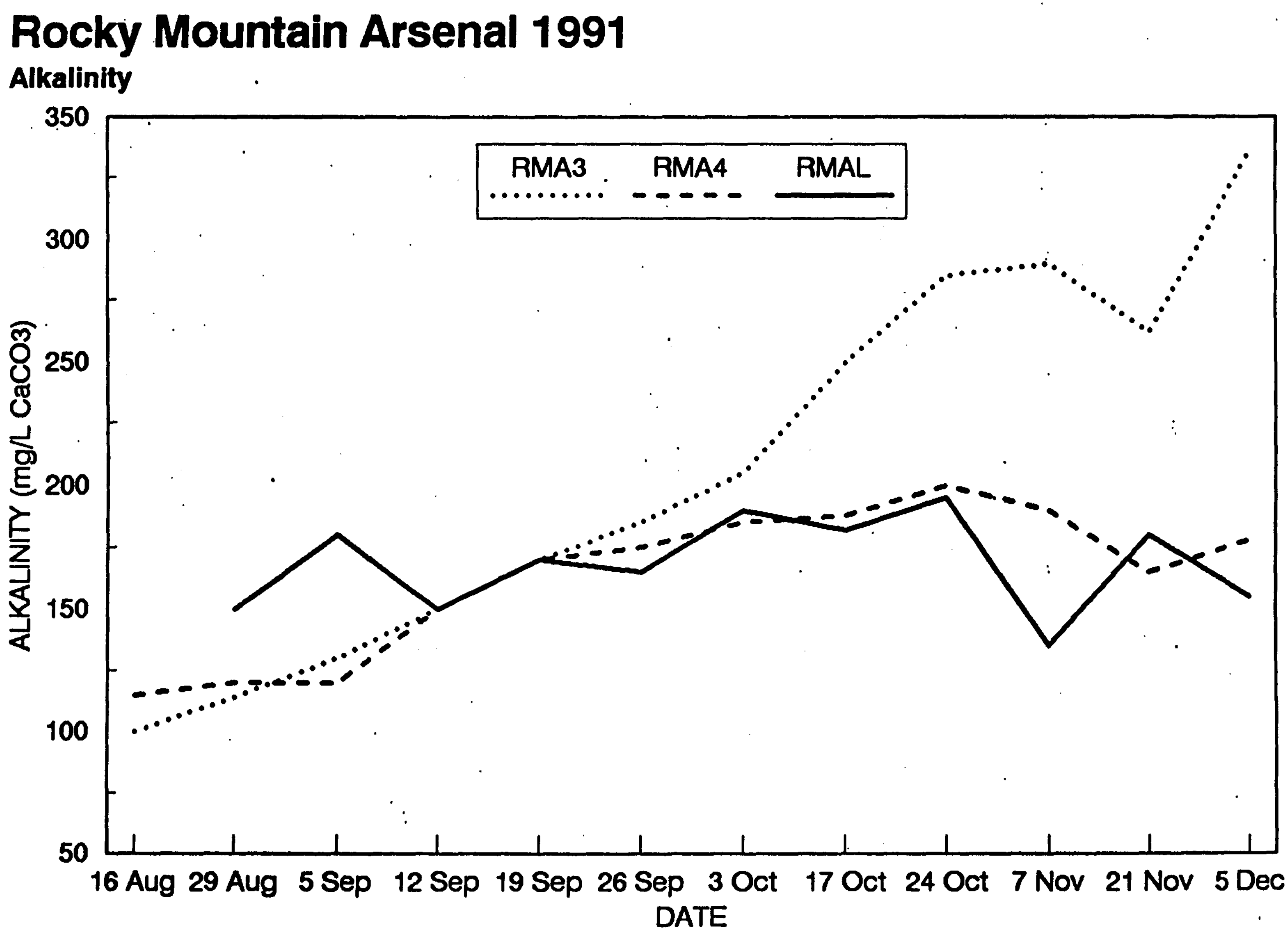

Rocky Mountain Arsenal 1991
Alkalinity
ALKALINITY (mg/L CaCO3)
350
300
250
200
150
100
50
RMA3
RMA4
RMAL
16 Aug
29 Aug
5 Sep
12 Sep
19 Sep
26 Sep
3 Oct
17 Oct
24 Oct
7 Nov
21 Nov
5 Dec
DATE

Figure 2

Rocky Mountain Arsenal 1991

Conductivity

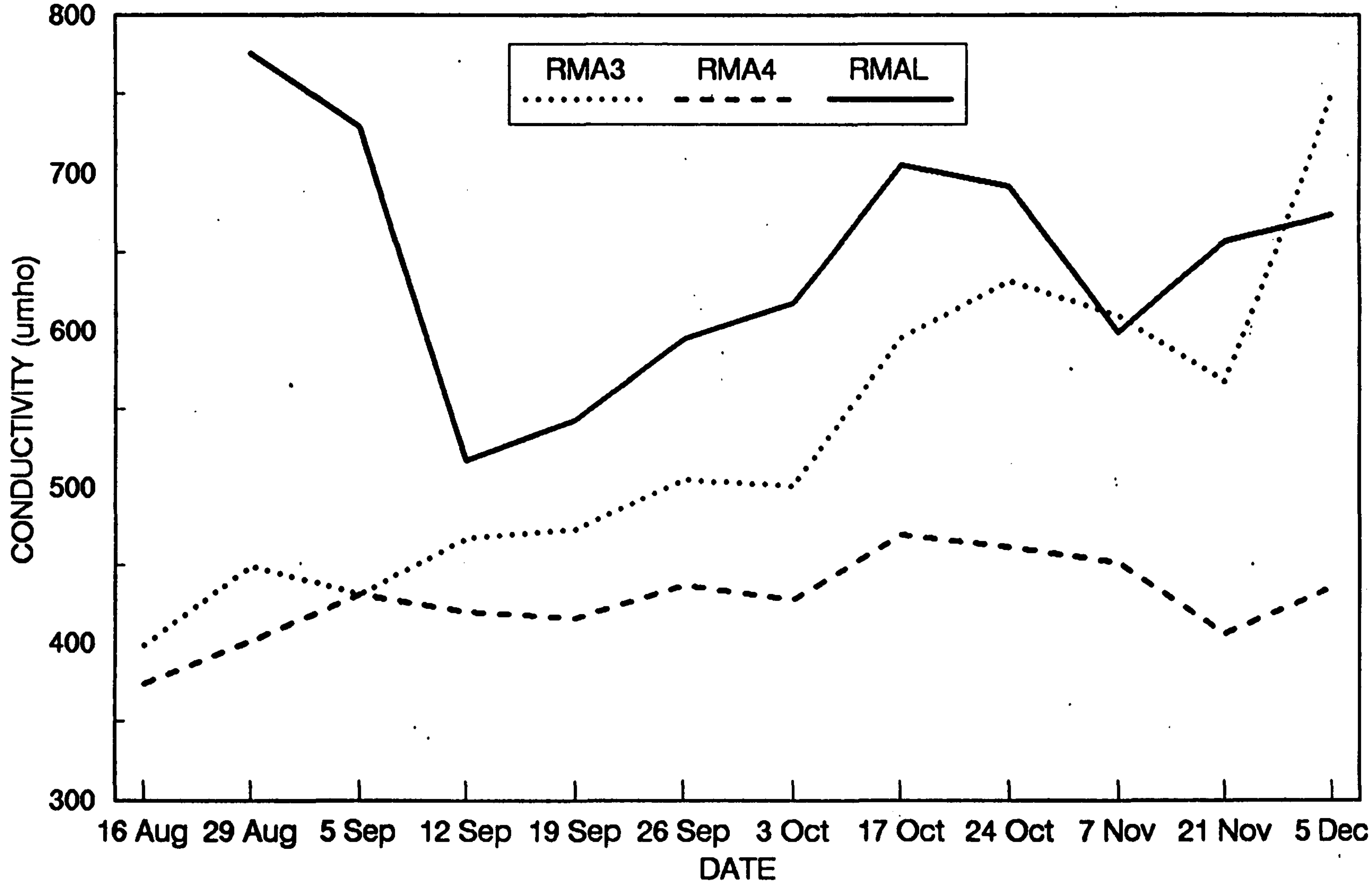
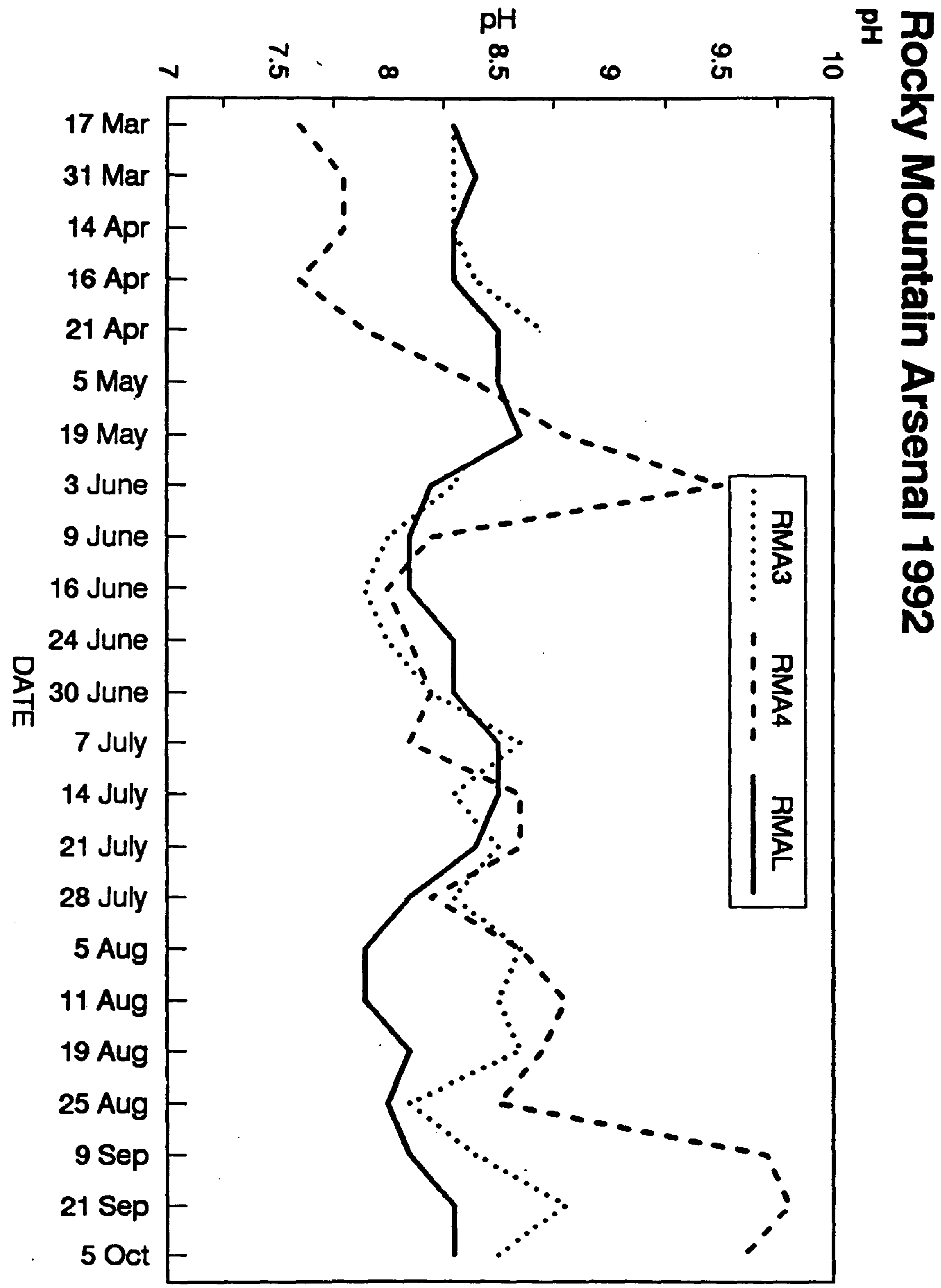
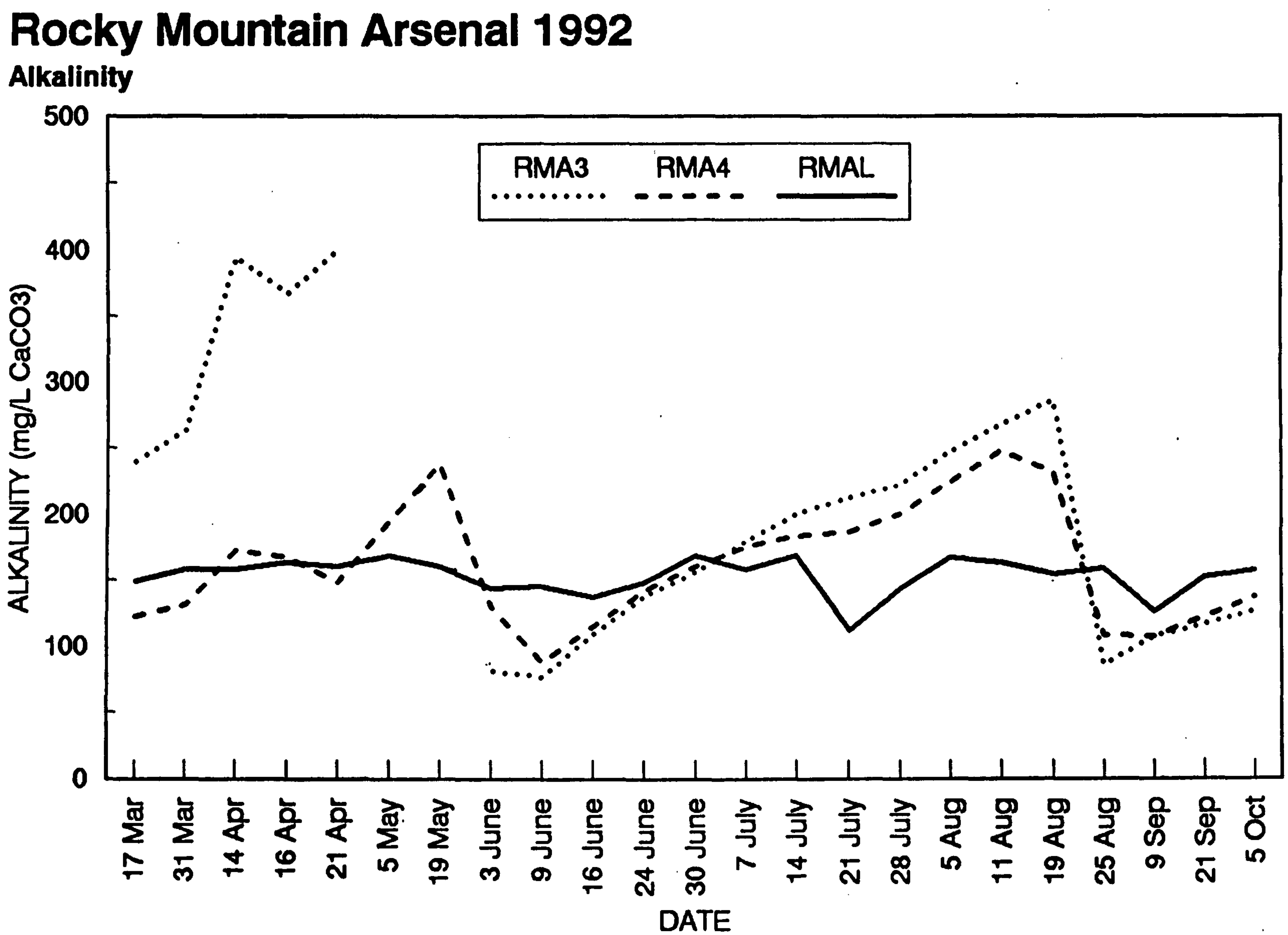


Figure 2



Rocky Mountain Arsenal 1992
pH
pH
7
7.5
8
8.5
9
9.5
10
17 Mar
31 Mar
14 Apr
16 Apr
21 Apr
5 May
19 May
3 June
9 June
16 June
24 June
30 June
7 July
14 July
21 July
28 July
5 Aug
11 Aug
19 Aug
25 Aug
9 Sep
21 Sep
5 Oct
DATE
RMA3
RMA4
RMAL

Figure 3



Rocky Mountain Arsenal 1992
Alkalinity
ALKALINITY (mg/L CaCO3)
0
100
200
300
400
500
RMA3
RMA4
RMAL
17 Mar
31 Mar
14 Apr
16 Apr
21 Apr
5 May
19 May
3 June
9 June
16 June
24 June
30 June
7 July
14 July
21 July
28 July
5 Aug
11 Aug
19 Aug
25 Aug
9 Sep
21 Sep
5 Oct
DATE

Figure 3

Rocky Mountain Arsenal 1992

Hardness

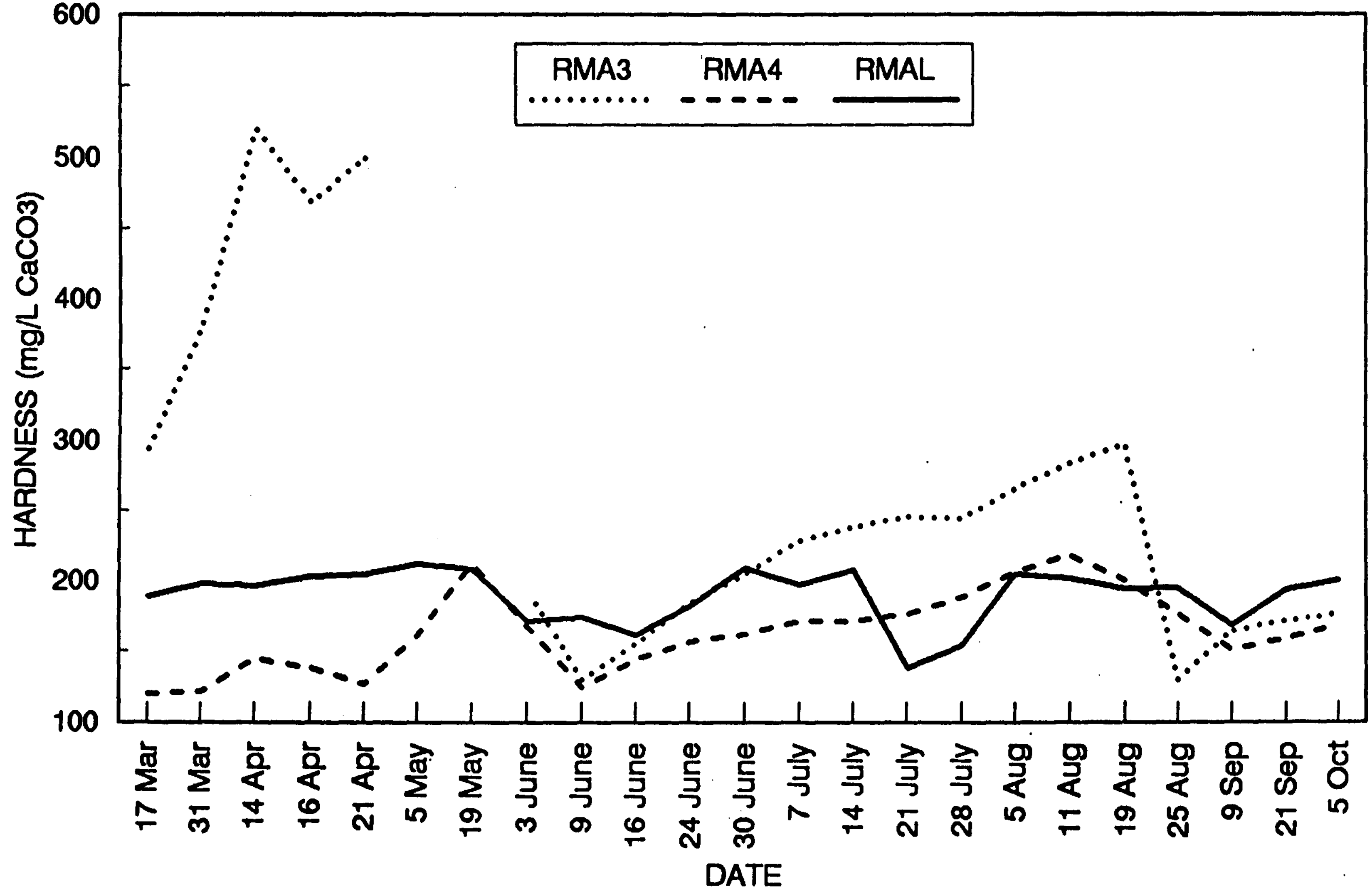


Figure 3

Rocky Mountain Arsenal 1992

Conductivity

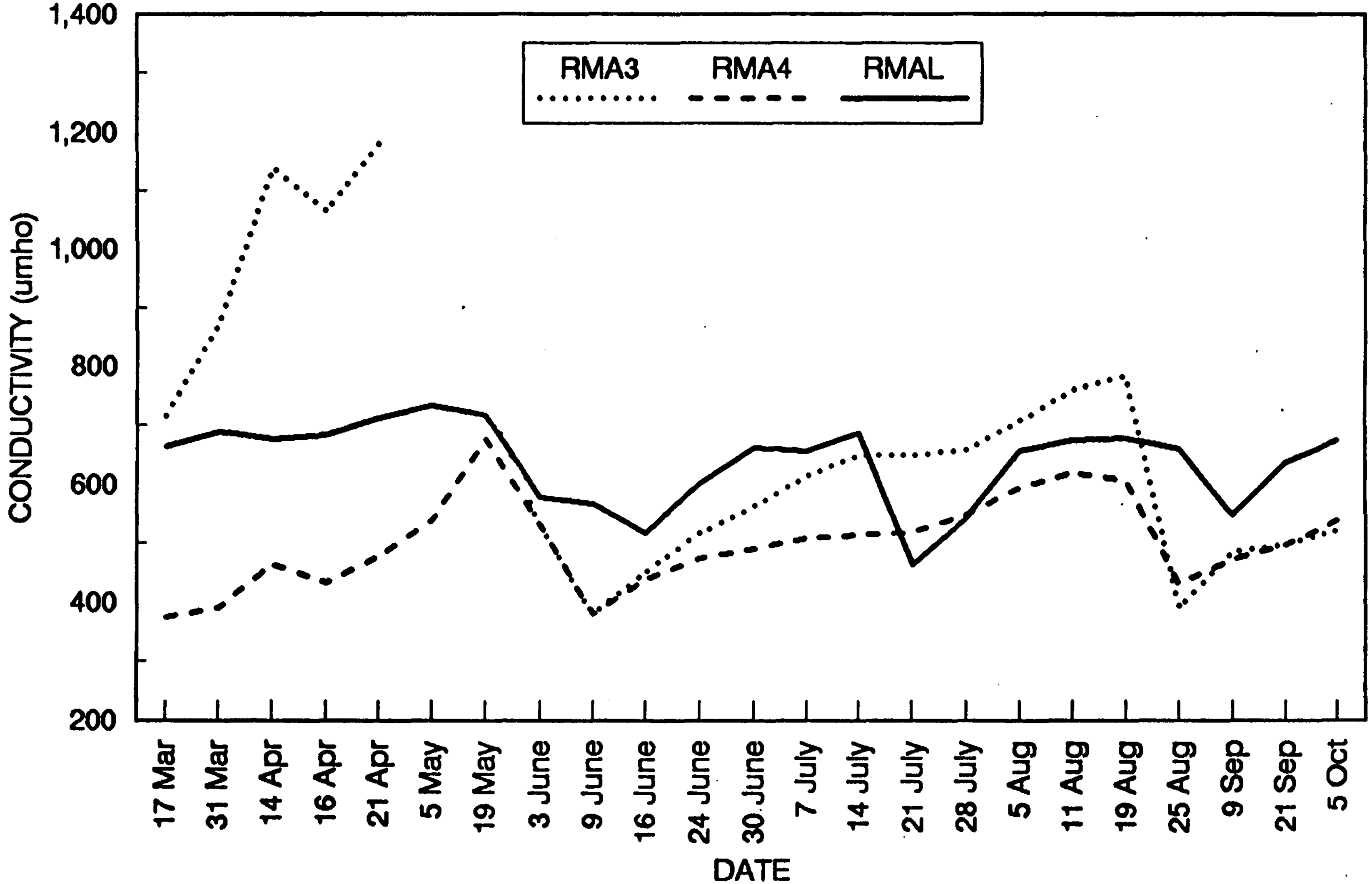


Figure 3

Average Number of Neonates

December 1991

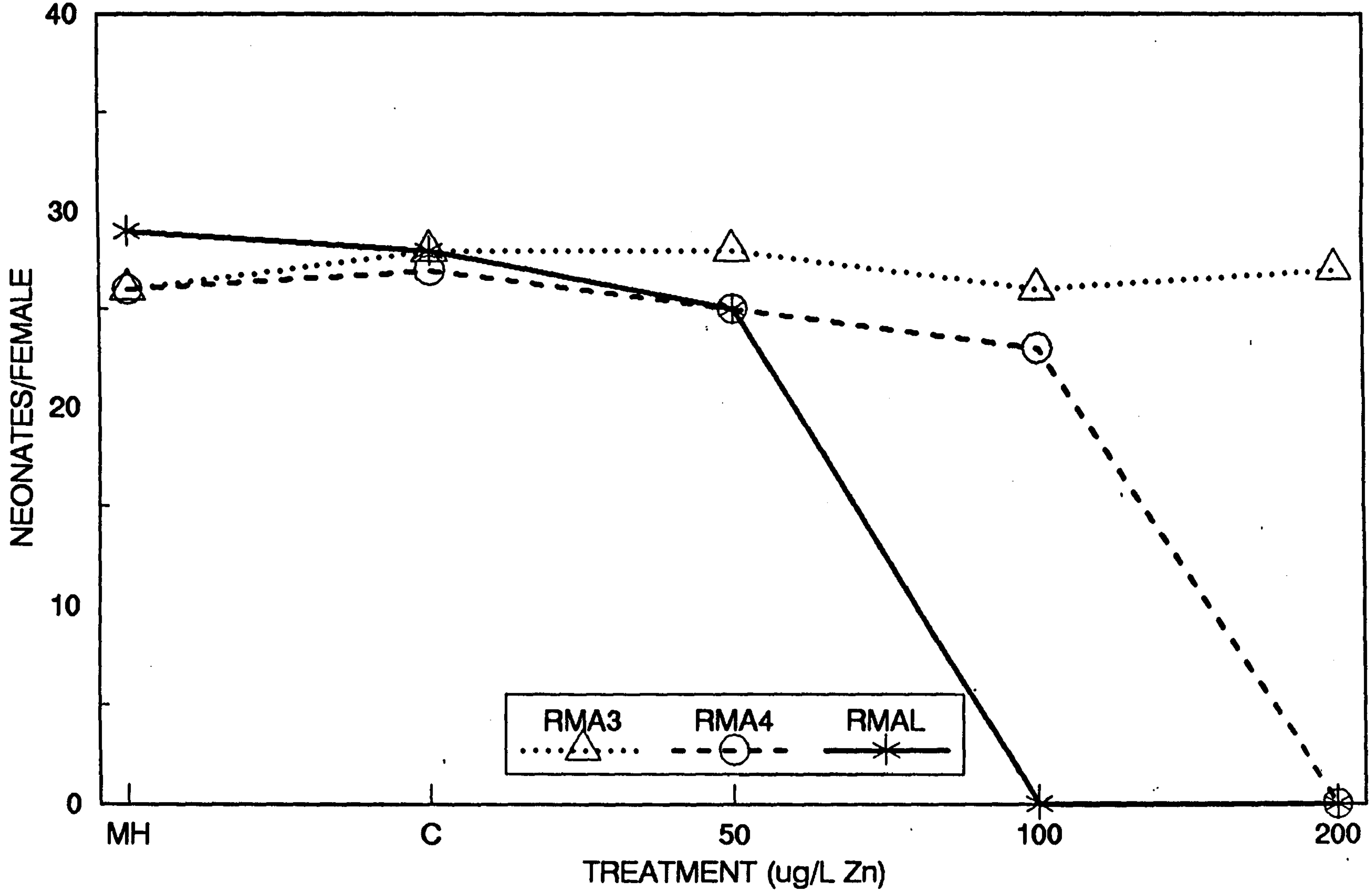


Figure 4

Average Number of Neonates

February 1992

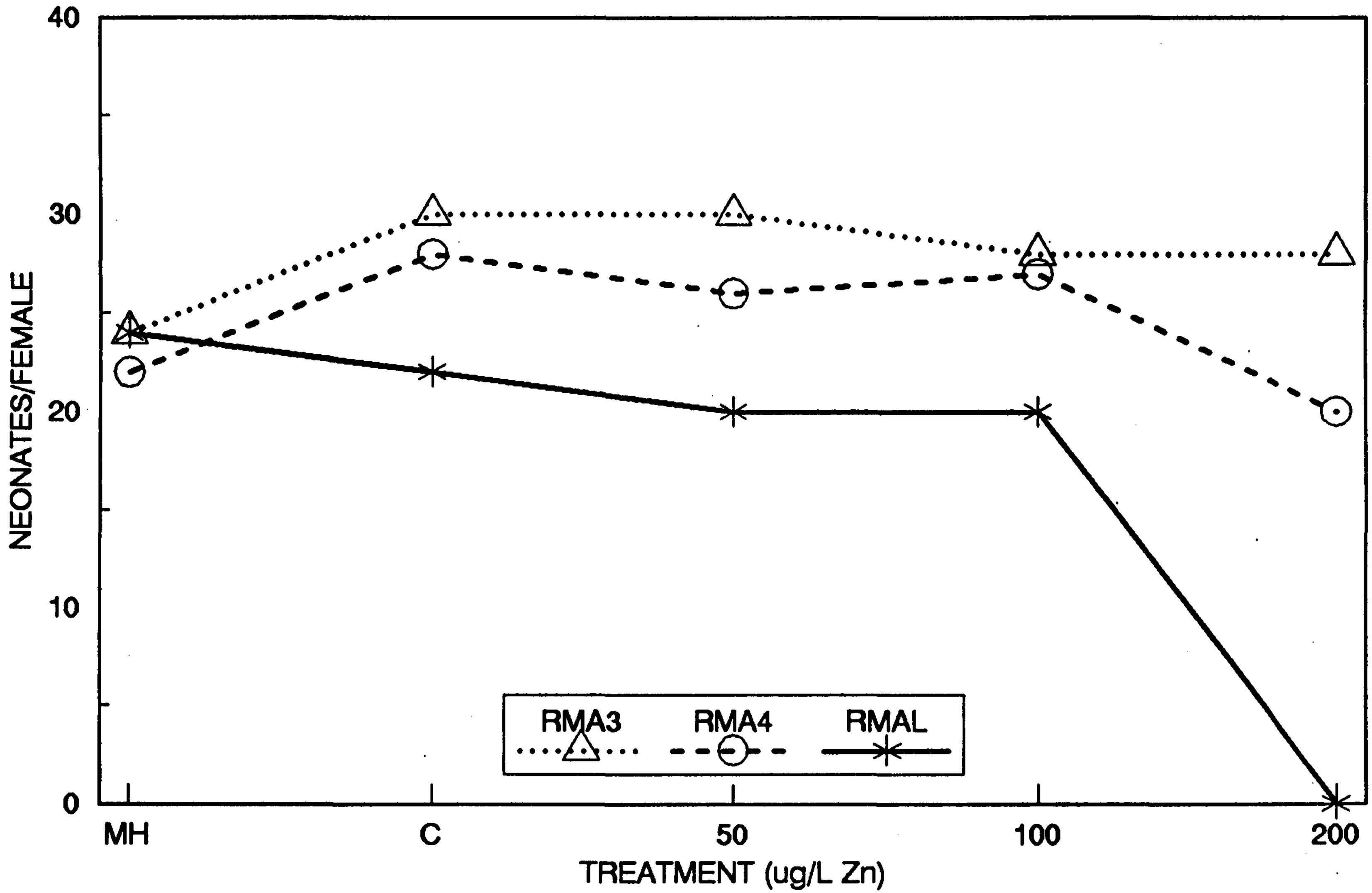
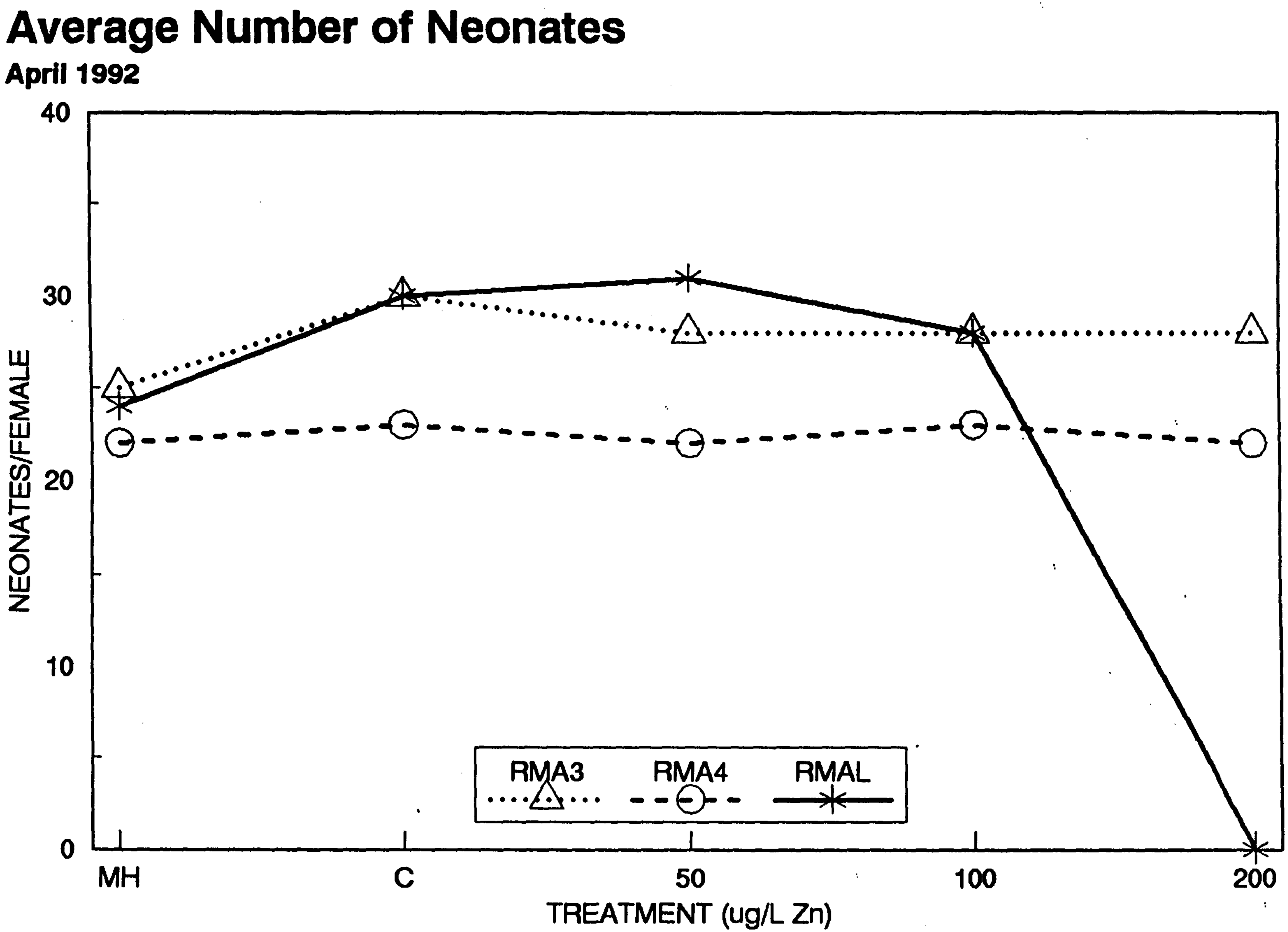
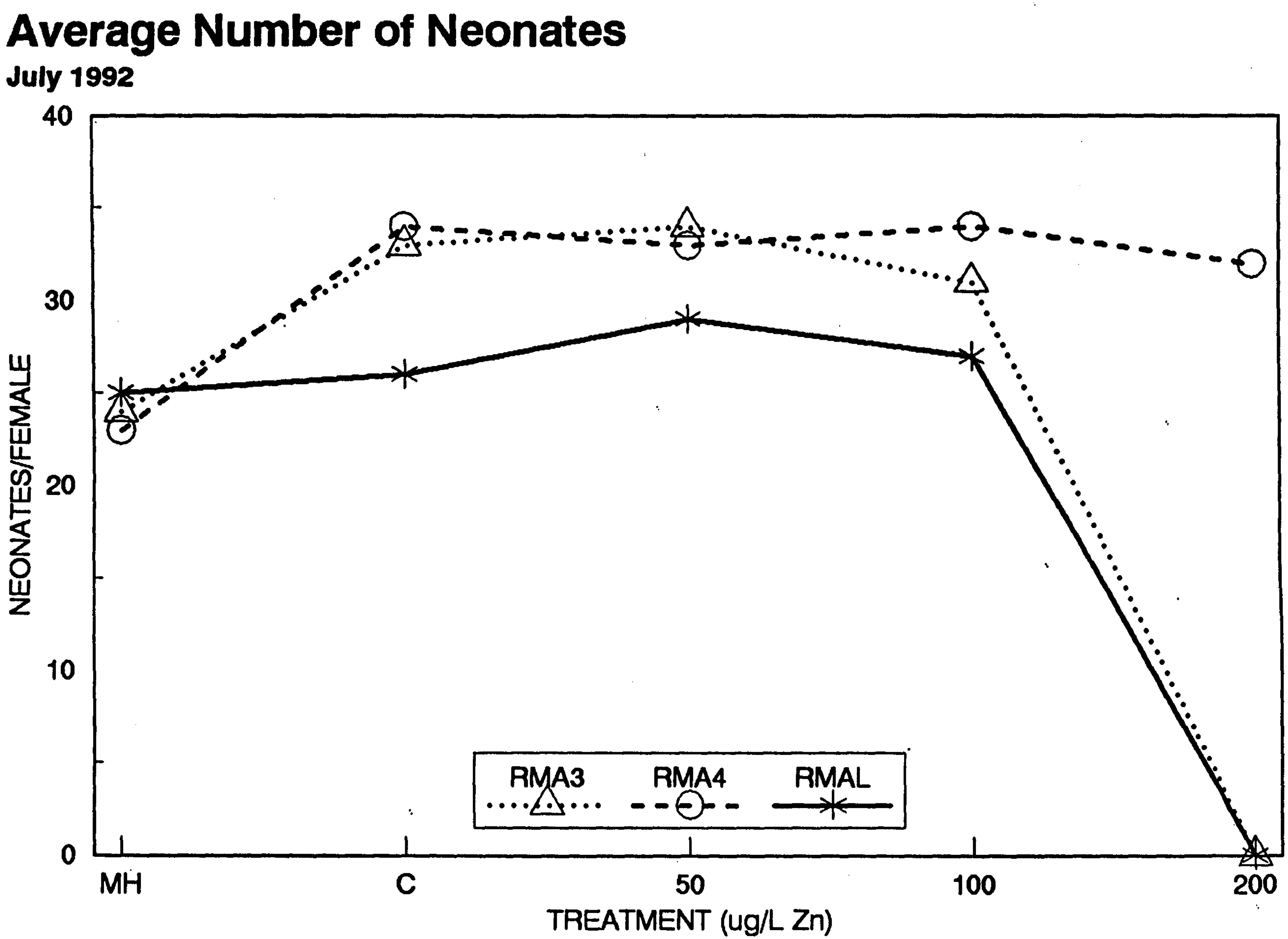


Figure 4

Figure 4



Average Number of Neonates
April 1992
40
30
20
10
0
NEONATES/FEMALE
MH
C
50
100
200
TREATMENT (ug/L Zn)
RMA3
RMA4
RMAL



Average Number of Neonates
July 1992
NEONATES/FEMALE
40
30
20
10
0
MH
C
50
100
200
TREATMENT (ug/L Zn)
RMA3
RMA4
RMAL

Figure 4

Appendix 1. Water quality and physical data collected from wetlands and Ladora Lake, 1991-1992.

1991

STA	DATE	WEEK	pH	ALK	HARD	COND (umho)	TEMP (dec C)	D.O. (mg/L)	TOTAL DEPTH (M)	SECCHI DEPTH (M)
RMA1	16 Aug	1	-	-	-	-	-	-	-	-
	29 Aug	2	-	-	-	-	-	-	-	-
	5 Sep	3	-	-	-	-	-	-	-	-
	12 Sep	4	-	-	-	-	-	-	-	-
	19 Sep	5	-	-	-	-	-	-	-	-
	26 Sep	6	-	-	-	-	-	-	-	-
	3 Oct	7	-	-	-	-	-	-	-	-
	17 Oct	8	-	-	-	-	-	-	-	-
	24 Oct	9	8.9	220	62	890	11	9.5	-	0.13
	7 Nov	10	8.9	200	60	842	7	10.5	-	-
	21 Nov	11	-	-	-	-	-	-	-	-
	5 Dec	12	-	-	-	-	-	-	-	-
	11 Feb	13	-	-	-	-	-	-	-	-
RMA2	16 Aug	1	8	100	128	382	25	6.6	-	-
	29 Aug	2	8.8	75	122	267	31	8.1	-	-
	5 Sep	3	9.1	120	132	212	28.5	8.5	0.22	0.13
	12 Sep	4	9.8	115	134	407	26	15	0.17	0.06
	19 Sep	5	9.1	140	172	505	22.5	15	0.07	0.07
	26 Sep	6	-	-	-	-	-	-	-	-
	3 Oct	7	-	-	-	-	-	-	-	-
	17 Oct	8	-	-	-	-	-	-	-	-
	24 Oct	9	-	-	-	-	-	-	-	-
	7 Nov	10	-	-	-	-	-	-	-	-
	21 Nov	11	-	-	-	-	-	-	-	-
	5 Dec	12	-	-	-	-	-	-	-	-
	11 Feb	13	6.8	22	19	71	8.5	10.6	0.18	0.18
		mean:	8.6	95	118	307	23.6	10.6	0.16	0.11
		s:	3.38	45.5	53.8	162.7	10.27	5.16	0.055	0.048
RMA3	16 Aug	1	7.4	100	132	399	25.5	2	-	-
	29 Aug	2	8.8	114	144	449	27	8.2	-	-
	5 Sep	3	9.6	130	146	431	25	12	0.7	0.33
	12 Sep	4	7.8	150	158	467	22	3.7	0.59	0.32
	19 Sep	5	7.4	170	176	473	15.5	4.1	0.56	0.33
	26 Sep	6	7.9	185	182	505	21	6.7	0.37	btm
	3 Oct	7	7.9	205	190	501	18	8.3	0.31	0.3
	17 Oct	8	8.2	250	222	596	16	8.2	0.46	0.28
	24 Oct	9	7.8	285	246	632	11	6.2	0.43	0.22
	7 Nov	10	8.1	290	252	610	7	9.7	0.37	0.2
	21 Nov	11	8.2	262	242	568	8	10.4	0.35	0.16
	5 Dec	12	7.7	336	316	750	4	11.8	0.3	0.19
	11 Feb	13	7.5	134	118	312	8.5	5.9	0.06	btm
		mean:	8.0	201	194	515	16.0	7.5	0.41	0.33
		s:	0.58	73.6	55.6	110.2	7.48	2.97	0.163	0.27

Appendix 1.(continued)

<u>1991</u>

STA	DATE	WEEK	pH	ALK	HARD	COND (umho)	TEMP (dec C)	D.O. (mg/L)	TOTAL DEPTH (M)	SECCHI DEPTH (M)
RMA4	16 Aug	1	7.2	115	128	374	26	2.5	-	-
	29 Aug	2	8.1	120	134	401	27	8.1	-	-
	5 Sep	3	7.9	120	146	431	26	8.8	0.81	0.32
	12 Sep	4	8	150	146	420	22	7.1	0.73	0.33
	19 Sep	5	7.8	170	156	416	16.5	9	0.67	0.31
	26 Sep	6	8.1	175	160	437	20	10.6	0.63	0.35
	3 Oct	7	8	185	164	428	17	9.4	0.56	0.31
	17 Oct	8	8.2	188	166	470	15	8.2	0.73	0.29
	24 Oct	9	8	200	164	462	11	8.8	0.69	0.3
	7 Nov	10	7.8	190	160	452	5	9.8	0.67	0.3
	21 Nov	11	8.1	165	148	406	6	11.4	0.67	0.28
	5 Dec	12	7.5	178	165	436	5	10.2	0.64	0.4
	11 Feb	13	7.0	125	120	368	3.5	9.8	0.61	btm
		mean:	7.8	160	151	423	15.4	8.7	0.67	0.32
		std:	0.36	29.3	14.6	29.5	8.29	2.11	0.064	0.033
RMA5	16 Aug	1	-	-	-	-	-	-	-	-
	29 Aug	2	-	-	-	-	-	-	-	-
	5 Sep	3	7.4	110	140	433	25	1.4	0.8	0.73
	12 Sep	4	7.4	140	152	457	23	1	0.57	0.25
	19 Sep	5	8.1	165	164	465	19	10.2	0.37	btm
	26 Sep	6	7.6	175	174	510	25	7.3	0.18	btm
	3 Oct	7	-	-	-	-	-	-	-	-
	17 Oct	8	-	-	-	-	-	-	-	-
	24 Oct	9	-	-	-	-	-	-	-	-
	7 Nov	10	-	-	-	-	-	-	-	-
	21 Nov	11	-	-	-	-	-	-	-	-
	5 Dec	12	-	-	-	-	-	-	-	-
	11 Feb	13	-	-	-	-	-	-	-	-
		mean:	7.6	148	158	466	23.0	5.0	0.48	0.49
		std:	0.29	25.1	12.8	27.9	2.45	3.91	0.231	0.240
RMAL	16 Aug	1	-	-	-	-	-	-	-	-
	29 Aug	2	8	150	206	775	-	-	-	-
	5 Sep	3	8.3	180	202	729	24	8.6	1.01	0.9
	12 Sep	4	8.1	150	168	517	23	7.1	1.21	1
	19 Sep	5	8	170	180	543	18.5	7.9	1.04	0.83
	26 Sep	6	8.5	165	186	595	19.5	12.2	0.99	btm
	3 Oct	7	8.4	190	214	618	19	12	0.99	btm
	17 Oct	8	8.6	182	210	705	15	9.2	-	btm
	24 Oct	9	8.5	195	210	692	12	9.9	-	btm
	7 Nov	10	8.8	135	162	599	4.5	10.7	-	-
	21 Nov	11	8.4	180	204	657	5	11.2	-	btm
	5 Dec	12	8.5	155	186	674	3	13	0.82	btm
	11 Feb	13	8.6	154	198	678	5.5	15	1.11	0.72
		mean:	8.39	167	194	649	12.4	9.7	1.20	0.86
		std:	0.24	17.8	16.5	72.9	8.12	3.64	0.337	0.102

Appendix 1.(continued)
1992

STA	DATE	WEEK	pH	ALK	HARD	COND (umho)	TEMP (deg C)	D.O. (mg/L)	T.DEPTH (M)	SECCHI DEPTH(M)
RMA1	17 Mar	1	9.2	119	88	364	10	8.7	0.55	0.06
	31 Mar	2	8.9	142	94	411	9.5	9.4	0.4	0.06
	14 Apr	3	8.8	196	127	520	19	7.9	0.06	0.24
	16 Apr	4	8.8	198	129	517	14	9.4	-	0.06
	21 Apr	5	-	-	-	-	-	-	-	-
	5 May	6	8.9	287	94	916	12	8.1	0.52	0.17
	19 May	7	8.8	102	130	455	20	8	1.43	0.95
	3 June	8	7.8	96	123	415	19	7.5	1.83	0.65+
	9 June	9	8	94	120	398	18.5	3.9	2.03	1.10+
	16 June	10	8	92	124	389	23	3.7	2.12	0.75+
	24 June	11	8	110	138	423	24.5	1.7	2.13	0.71+
	30 June	12	8	115	142	441	23	4.5	2.04	-
	7 July	13	8.1	132	151	465	24.5	4	1.95	1.03+
	14 July	14	8.2	142	151	484	24.5	5	1.87	0.99+
	21 July	15	8.3	142	152	470	25	6.4	1.83	0.91
	28 July	16	7.9	151	156	490	25	5	1.75	0.72
	5 Aug	17	8.3	160	156	510	22	5.4	1.65	0.66
	11 Aug	18	8.8	163	155	509	25	9.1	1.57	0.74
	19 Aug	19	9.1	156	142	494	24	14.3	1.51	0.81
	25 Aug	20	9.2	92	104	386	19	10.2	1.83	0.65
	9 Sep	21	8.9	84	113	410	18.5	8.2	2.09	1
	21 Sep	22	8.4	112	133	458	19	8.4	1.92	0.75
	5 Oct	23	8.8	105	130	474	17	9.9	1.77	0.86
		mean:	8.5	136	130	473	19.8	7.2	1.84*	-
		s:	0.45	45.9	20.5	106.9	4.77	2.79	0.206	-
RMA2	17 Mar	1	7.5	15	15	81	13	9.9	0.16	0.12
	31 Mar	2	7.4	22	26	62	11	9.6	0.17	0.06
	14 Apr	3	-	-	-	-	-	-	-	-
	16 Apr	4	-	-	-	-	-	-	-	-
	21 Apr	5	-	-	-	-	-	-	-	-
	5 May	6	-	-	-	-	-	-	-	-
	19 May	7	7.8	110	156	502	27	7.1	0.64	btm
	3 June	8	7.8	93	127	415	21.5	5.2	0.73	0.68
	9 June	9	7.7	74	106	346	16	3.8	0.79	0.41
	16 June	10	8.1	86	123	384	22	2.9	0.72	btm
	24 June	11	8	87	132	398	25	7.3	0.73	btm
	30 June	12	8.1	102	147	432	22	5	0.58	btm
	7 July	13	8	110	158	459	22.5	4.2	0.4	btm
	14 July	14	8.2	108	156	478	23.5	7.6	0.3	btm
	21 July	15	8	76	85	263	21.5	6	0.35	0.25
	28 July	16	7.8	95	107	318	24.5	10.2	0.24	0.21
	5 Aug	17	8.9	124	131	384	22	11.6	0.21	0.19
	11 Aug	18	8.8	147	158	444	20.5	9	0.15	0.1
	19 Aug	19	8.4	199	188	519	26	8.4	0.14	0.18
	25 Aug	20	7.8	68	114	351	15.5	6.1	0.79	btm
	9 Sep	21	7.9	90	152	488	17	5.2	0.64	0.56
	21 Sep	22	7.7	138	204	636	20.2	5.7	0.27	0.09
	5 Oct	23	8.1	82	170	654	16	13.6	0.17	0.02
		mean:	8	96	129	401	20.4	7.3	0.43	-
		s:	0.37	40	46.8	147.4	4.32	2.75	0.245	-

Appendix 1.(continued)

1992

STA	DATE	WEEK	pH	ALK	HARD	COND (umho)	TEMP (deg C)	D.O. (mg/L)	TOTAL DEPTH (M)	SECCHI DEPTH (M)
RMA3	17 Mar	1	8.3	240	294	716	11.5	7	0.17	btm
	31 Mar	2	8.3	264	380	873	11.5	8.6	0.18	btm
	14 Apr	3	8.3	395	520	1139	20	8.8	0.12	btm
	16 Apr	4	8.4	367	469	1065	14	9.9	0.12	btm
	21 Apr	5	8.7	400	500	1180	19.5	2	0.09	btm
	5 May	6	-	-	-	-	-	-	-	-
	19 May	7	-	-	-	-	-	-	-	-
	3 June	8	8.3	81	194	530	23.5	8.4	0.34	btm
	9 June	9	8	77	130	381	17.5	5.7	1.02	0.59
	16 June	10	7.9	109	155	452	22.5	0.3	1.08	0.55
	24 June	11	8	138	184	519	24.5	5.8	0.98	0.67
	30 June	12	8.2	156	204	563	23.5	8.8	-	0.91
	7 July	13	8.6	179	228	614	26	9	0.84	0.39
	14 July	14	8.3	200	238	650	27	8.5	0.78	btm
	21 July	15	8.5	212	245	650	23.5	8.1	0.73	btm
	28 July	16	8.3	222	244	660	27	9	0.67	0.57
	5 Aug	17	8.6	247	265	707	25.5	7.5	0.56	btm
	11 Aug	18	8.5	268	283	760	25	7.2	0.49	btm
	19 Aug	19	8.6	286	297	785	26.5	9.7	0.43	btm
	25 Aug	20	8.1	86	130	392	18	6.3	1.26	0.61
	9 Sep	21	8.4	107	164	486	19	8.6	1.3	1.06+
	21 Sep	22	8.8	116	171	499	19.5	10.3	1.17	btm
	5 Oct	23	8.5	127	176	523	17	10.4	1.05	btm
		mean:	8.4	204	260	674	21	7.6	0.67	-
		s:	0.23	98.6	113.5	223.9	4.74	2.48	0.41	-
RMA4	17 Mar	1	7.6	122	120	376	10	7	0.58	0.37
	31 Mar	2	7.8	131	122	392	11	8.6	0.56	0.28
	14 Apr	3	7.8	172	145	465	20	6.2	0.47	btm
	16 Apr	4	7.6	167	138	435	14	3.3	0.48	0.46
	21 Apr	5	7.9	148	127	478	11.5	5.5	0.46	btm
	5 May	6	8.4	194	161	540	25	13.6	0.34	btm
	19 May	7	8.8	238	212	677	26.5	15	0.31	0.16
	3 June	8	9.5	130	167	532	28	15	0.4	0.19
	9 June	9	8.2	88	125	380	18.5	6.3	1.17	0.65
	16 June	10	8	115	144	440	22.5	5.4	1.1	0.7
	24 June	11	8.1	142	157	476	24.5	5.8	1	0.72
	30 June	12	8.2	160	162	492	23	5.5	0.98	btm
	7 July	13	8.1	175	171	510	25.5	6	0.91	btm
	14 July	14	8.6	183	171	515	28	9.3	0.88	0.56
	21 July	15	8.6	186	176	520	27	8.5	0.85	0.41
	28 July	16	8.2	200	188	549	26.5	8.9	0.81	0.39
	5 Aug	17	8.6	224	206	595	25.5	8.6	0.73	0.38
	11 Aug	18	8.8	248	218	620	25.5	10.6	0.69	0.37
	19 Aug	19	8.7	232	200	607	27	10.5	0.64	0.53
	25 Aug	20	8.5	108	176	432	19	8.8	1.02	btm
	9 Sep	21	9.7	107	151	474	19	12.8	1.14	btm
	21 Sep	22	9.8	122	159	499	19.5	13.8	1.04	btm
	5 Oct	23	9.6	137	168	539	18	10.2	0.93	btm
		mean:	8.5	162	164	502	21.5	8.9	0.76	-
		s:	0.64	44.6	27.6	75.3	5.54	3.27	0.265	-

Appendix 1.(continued)

1992

STA	DATE	WEEK	pH	ALK	HARD	COND (umho)	TEMP (deg C)	D.O. (mg/L)	TOTAL DEPTH (M)	SECCHI DEPTH (M)
RMA5	17 Mar	1	-	-	-	-	-	-	-	-
	31 Mar	2	-	-	-	-	-	-	-	-
	14 Apr	3	-	-	-	-	-	-	-	-
	16 Apr	4	-	-	-	-	-	-	-	-
	21 Apr	5	-	-	-	-	-	-	-	-
	5 May	6	-	-	-	-	-	-	-	-
	19 May	7	-	-	-	-	-	-	-	-
	3 June	8	-	-	-	-	-	-	-	-
	9 June	9	8.1	76	98	301	17	7.5	0.52	btm
	16 June	10	8	90	132	397	23.5	3.2	0.79	0.75
	24 June	11	8	86	122	370	25	1.1	0.91	btm
	30 June	12	8	103	131	380	26	2.5	0.78	-
	7 July	13	8	121	140	402	27	4.9	0.64	btm
	14 July	14	7.8	144	149	413	24	0.4	0.55	0.41
	21 July	15	8.2	144	146	406	29	5.6	0.44	0.3
	28 July	16	7.9	149	148	412	26	5	0.3	btm
	5 Aug	17	8.8	150	138	405	28.5	13.5	0.25	btm
	11 Aug	18	-	-	-	-	-	-	-	-
	19 Aug	19	-	-	-	-	-	-	-	-
	25 Aug	20	8.3	70	112	338	18.5	9.3	0.69	btm
	9 Sep	21	7.5	92	135	418	18	6.9	0.88	btm
	21 Sep	22	7.9	138	146	449	19.5	5.1	0.64	btm
	5 Oct	23	8.0	137	158	486	19	7.2	0.4	btm
		mean:	8.0	115	135	398	23.2	5.6	0.60	-
		s:	0.29	28.8	15.8	44.2	4.06	3.37	0.204	-
RMAL	17 Mar	1	8.3	149	189	665	10.5	10.6	0.9	btm
	31 Mar	2	8.4	158	198	689	11.5	9.4	0.89	btm
	14 Apr	3	8.3	158	196	678	16.5	9.2	0.8	btm
	16 Apr	4	8.3	163	203	685	15.5	9.2	0.8	btm
	21 Apr	5	8.5	160	204	713	15	9.8	0.8	btm
	5 May	6	8.5	168	212	734	21.5	12.3	0.8	btm
	19 May	7	8.6	160	208	719	24	12.9	0.7	btm
	3 June	8	8.2	144	171	579	21.5	11	0.7	-
	9 June	9	8.1	145	174	568	22	6.1	-	btm
	16 June	10	8.1	137	161	518	23.5	8.8	-	btm
	24 June	11	8.3	148	182	602	24.5	7.4	-	btm
	30 June	12	8.3	168	209	663	26	10.3	-	btm
	7 July	13	8.5	158	197	658	25.5	10.6	-	btm
	14 July	14	8.5	168	207	688	27	10.1	-	btm
	21 July	15	8.4	112	138	465	26.5	7.2	-	0.69
	28 July	16	8.1	143	154	543	27	5.3	-	btm
	5 Aug	17	7.9	167	204	657	25	4.8	-	btm
	11 Aug	18	7.9	163	201	675	24	6.7	-	btm
	19 Aug	19	8.1	154	194	679	25	8	-	btm
	25 Aug	20	8	159	195	661	20.5	5.5	-	btm
	9 Sep	21	8.1	126	168	549	20	7.5	-	btm
	21 Sep	22	8.3	152	193	638	19.5	8.4	-	btm
	5 Oct	23	8.3	157	200	676	16	9.7	-	btm
		mean:	8.3	153	189	639	21.2	8.7	-	-
		s:	0.19	13.6	19.2	68.6	4.81	2.13	-	-

Appendix 1.(continued)

*The mean and standard deviation for total depth of RMA1 (1992) do not include values from 17 March through 5 May.

THE CREATION OF WETLANDS AT THE ROCKY MOUNTAIN ARSENAL: MONITORING THE TRENDS AND PROCESSES OF VEGETATION ESTABLISHMENT ON SHORT AND LONG TIME SCALES AND ALONG WATER TABLE GRADIENTS

1992 ANNUAL REPORT

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INTRODUCTION

The purpose of this research project is to investigate how to best create and manage wetlands on the Rocky Mountain Arsenal. It is also an attempt to gain an understanding of some of the ecological processes associated with wetlands creation.

Specifically, we will examine how wetland communities form, how succession rates vary along hydrologic gradients, and how rates of succession and community composition are affected by the introduction of plant propagules and vegetation manipulation. This report describes work completed and results of the first year.

Several hypotheses are the focus of this research and are listed below:

1. Wetland communities develop most rapidly in the wetter portions of the water table gradient. Thus, aquatic communities can be fully developed in just a few years, emergent communities in several years and wetland margin communities may take many years to develop. Thus, efforts to affect community composition must occur at different time scales in different portions of the hydrologic regime.

2. The composition of emergent wetland communities is determined by competition with cattail (Typha spp.).

3. The hydrologic regime and shape of the water table profile will determine the extent of wetland margin communities.

4. Soil redox potential is a more accurate predictor of community composition than any one hydrologic variable.

METHODS

Five landscape depressions were chosen to create wetlands in the southeast corner of the Rocky Mountain Arsenal. Each wetland is numbered 1 through 5. At each wetland, transects were established along the most gentle and well defined gradients from the center of the basin to the uplands. Wetlands 1, 3, and 4 have 4 transects each while wetlands 2 and 5 have 3 transects each. A total of 121 stations were established along the transects where all measurements and observations were taken. At each station, a permanent 6 square meter plot was marked with an orange-tipped metal rod at each corner for measuring plant growth and species composition. A shallow groundwater monitoring well was installed at each station where permanent flooding was not anticipated. Metal staff gauges were installed at stations where permanent standing water was expected. Depth to water table or depth of standing water was measured weekly from June through September and once in November before the wells froze. The wells and staff gauges were surveyed for position and elevation by Morrison Knudsen Engineers, Inc. Ten of the 121 stations were chosen to monitor oxidation - reduction (redox) potential at 5, 10 and 20 cm soil depths.

A combination of live planting, seeding and vegetation manipulation is being carried out at each wetland in an attempt to determine the influence of these prescriptions on rates of succession and community composition. Seeds were collected in the fall of 1991 and broadcast along the east margins 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
Scirpus acutus	75	75	75	75
Scirpus paludosus	235	110	110	110
Sparganium eurycarpum	15	15	15	15

Number of seeds

Species	Wetland# 1	3	4	5
Scirpus acutus	100,000	100,000	100,000	100,000
Scirpus 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. Most plants were collected as individuals; however, some were in clumps containing several 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

Number	Plant Species
86	*Scirpus acutus*
75	*Scirpus americanus*
60	*Scirpus paludosus*
47	*Scirpus lacustris*

Wetland 3

Number	Plant Species
8	Scirpus paludosus
21	Sparganium eurycarpum
14	Sagittaria cuneata
5	Juncus compressus
14	Hippuris vulgaris
9	Carex nebraskensis
2	Veronica anagallis-aquatica
	Lemna minor (approximately 10 liters)

Wetland 4

Number	Plant Species
51	Scirpus acutus
128	Scirpus americanus
88	Scirpus paludosus
90	Persicaria amphibia
2	Juncus torreyi
1	Asclepias incarnata

Typha latifolia is an emergent plant that quickly invades new or disturbed wetland sites. In many cases it forms dense, homogeneous stands often outcompeting all other plant species. 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.

Vegetation data was analyzed using two multivariate methods. Classification was performed using the divisive hierarchical cluster analysis technique "two way indicator species index" available through the TWINSPAN (Hill 1979) computer program. Direct gradient analysis of species and environmental data was performed using Canonical Community Ordination in the computer program CANOCO (ter Braak 1988). Canonical Community Ordination performs multivariate direct gradient analysis by constraining the ordination axes using environmental data. This analysis allows researchers to interpret species and community level differences along several different environmental gradients simultaneously. The vegetation data used in this analysis was the canopy coverage for each plant species occurring in each study plot. The environmental data utilized was collected on site and included total number of days flooded, number of days not flooded, mean water depth, maximum water depth, number of days with reducing conditions at 5, 10 and 20 cm soil depths, whether the wetland basin was a preexisting wetland or not, and study treatment (combinations of planting species and removing cattails).

RESULTS AND DISCUSSION

Hydrology

Hydrologic studies of the five wetlands were conducted with several goals in mind. 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 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 of water loss from each wetland and the influence of the naturally occurring ground water table on the 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 feeder ditches from the main canal. Due to its higher elevation, wetland 1 is filled via a large pipe that syphons water from the canal.

Water availability to the Rocky Mountain Arsenal wetlands is sporadic with no scheduled delivery times or predetermined quantities. This sporadic supply results in extended periods of low water and in some cases dry conditions in several of the wetlands. Although seasonal drawdowns are common in prairie marshes, it is difficult to manipulate and manage vegetation in the wetlands without controlling the water regime.

Water was added to all of the wetlands in mid-June and allowed to draw down through mid-summer. This drawdown exposed mudflats along the wetland edges and allowed emergent vegetation to establish. After mid-summer, an attempt was made to maintain the water level within .5 feet of "full".

In general, the ground water table in the southeastern portion of the Rocky Mountain Arsenal appears to slope from the southeast to the northwest. Thus, the naturally occurring water table is higher in elevation on the south side of each wetland than on the north. This condition may ultimately allow wetland conditions to exist more extensively on the south side of each wetland where the water table is typically higher than on the other sides where the water table drops more rapidly.

The input of surface water to the five wetlands appears to create areas of ground water mounding directly under each wetland.

The mounds have steep sides, particularly on the north and although they grow laterally during the summer, they are of limited extent.

Wetland 1

Wetland 1 was created in an interdune basin. A dike has been constructed on its northern side in order 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 1 is a hydrologic profile from west to east of wetland 1. Wells 28 through 32 and 44 through 47 are on the upland edges while wells 33 through 43 and 48 through 51 are in the clay lined basin. On 19 May, water occupied the clay lined basin only. When Highline Canal water was introduced in early June, the entire lined and unlined wetland basin filled with surface water. Through June and July and into August, infiltration and evaporation caused the water level in wetland 1 to drop approximately three inches per week. Water syphoned from the Highline Canal accompanied by heavy rains in late August caused the water level to rise, after which a 3 inch per week water loss was observed again. On the western side, areas that were not inundated with surface water had water tables several feet below the lake level. 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 eastern side of the wetland.

Wetland 2

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 "playas" 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.

Several factors contributed to this wetland drying out often during the summer. A high surface area to volume ratio allowed evaporation to occur quickly. Evapotranspiration of water by the extensive 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 2 is a north-south hydrologic profile through wetland 2 and it shows that the surface water of this wetland is far above the ground water table.

Wetland 3

Wetland 3 is a naturally occurring interdune basin that historically was not a natural wetland. The topography surrounding this depression is such that diking and excavation were not needed to impound water.

Figure 3 is an east-west hydrologic profile showing a ground water mound under the wetland. It also shows that what appears to be the naturally occurring ground water table to the east of wetland 3 is higher than the adjacent ground water. For example, on 5 May ground water was more than 1.5 feet higher at well 36 than at well 40. Thus, a steep ground water slope exists from east to west.

Figure 4 provides a closer look at the ground water levels on the south side of wetland 3. The pattern for this profile is similar to that described for the eastern side of this wetland. Ground water to the south is at nearly the same elevation as surface water in the wetland on 5 May. Also, ground water levels at well 43 rise between 5 June and 30 June, most likely in response to the surface water in the Highline Canal or the building of a ground water mound at the wetland which was recharging the ground water table to the south.

Wetland 4

Wetland 4 is a natural seasonal wetland basin. When Highline Canal water was first introduced here in August of 1991, Marsilea mucronata and the spikerush Eleocharis palustris germinated and grew from the soil seed bank.

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 6 shows a west-east profile of wetland 4. It indicates pronounced ground water mounding, with surface water being three to five feet higher than ground water elevations. When examined together, the south-north and west-east profiles suggest wetland 4 loses water on the west, east and north sides and receives water from a high sloping groundwater table on the south at certain times of the year. For example, on 5 June 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 quickly. However, later in the summer after the wetland received Highline Canal water, the surface water levels were higher on all sides than the adjacent groundwater.

Wetland 5

Wetland 5 is a natural interdune basin that is not a historical wetland. The water table profiles shown in figures 7 and 8 indicate similar hydrologic processes occurring here as those occurring in the other four wetland basins. Ground water is naturally highest on the south as can be seen for 5 June in Figure 8. Ground water levels also drop off to the west on all dates, as illustrated in Figure 7.

Wetland 5 lost water the quickest 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.

SOILS

Oxidation-reduction (redox) potential was measured to help quantify the relationship between the hydrologic regime, the soil environment and plant distribution. This parameter will help 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 as they dry out.

Redox potential is an important measure of the soil environment due to its effect on rooted plants and the biochemical cycle. Only plants that have developed mechanisms to deal with anaerobic conditions can survive for extended periods of time in such environments. As a result, the length of time that soils are anaerobic and reduced can be used to determine whether or not a site is functioning as a wetland.

Redox potential is measured in millivolts (mv) and the scale runs from +700 to -300 mv. Soils are considered aerobic when redox potential is +300 mv or greater. Below 300 mv, soil oxygen becomes undetectable and soils are anaerobic. Soils with redox potentials from +300 to +100 mv are moderately reduced. Between +100 and -100 mv soils are said to be reduced and soils with redox potentials less than -100 are considered highly reduced.

Ten stations were chosen to examined redox potential in the wetlands. Stations 88, 89 and 90 are located along the south transect of wetland 4. Each station has a pair of redox electrodes at 5, 10 and 20 cm depths.

Station 88 was never flooded during the growing season but did have a water table close to the soil surface for approximately 6 weeks (Figure 9). The soil was aerobic at the 5 and 10 cm depths for the entire period of record. When the water table came within

1.5 feet of the soil surface, soil at the 20 cm depth quickly became anaerobic, probably within a few days. As the water table dropped below 1.5 feet, soils oxidized rapidly, again, probably within a few days. This illustrates how changes in depth to water table of even a few inches can have a dramatic effect on the biochemical environment in the root zone of plants.

Station 89 was inundated for 11 of the 84 days of record (Table 1). As the water table gradually dropped, redox potentials at all 3 soil depths rose simultaneously (Figure 10). At the 5 cm depth, conditions became aerobic for 7 days while at the 10 cm depth aerobic conditions existed for more than 3 weeks. At 20 cm, soils were anaerobic for the entire period of record even when the water table dropped 2-3 feet below the ground surface.

Station 90 was flooded early and late in the season and, as a result, soils were anaerobic during these times (figure 11). During late July, the water table dropped rapidly. This was followed by a steady rise in redox potential until, at the 5 and 20 cm depths, soils became aerobic. Although the water table dropped to more than 4 feet below the ground surface, soils at 10 cm remained anaerobic for the entire time.

This redox potential data shows that soils that are flooded for a short period of time (such as at station 89) or have a water table close to the soil surface (such as at station 88) during a portion of the growing season do become anaerobic and reduced. These conditions will eventually result in the elimination of upland plants and the establishment of hydrophytic plants at these sites.

This data also illustrates how quickly soils can change from aerobic to anaerobic conditions with a slight change in water table depth. For example, at station 88, a rise in the water table depth from 1.65 to 1.38 feet below the surface caused soils to become anaerobic within a few days.

The length of time that soils remain anaerobic and reduced after water tables drop illustrates the importance of using redox potential as an indicator of wetland conditions. If depth to water table was used alone to determine where a wetland could or could not occur, inaccurate conclusions could result.

Station #	# of days water within 1.5' of surface	# of days flooded	# of days anaerobic at electrode depth 5cm	10 cm	20cm
88	42	0	0	0	18
89	62	11	77	59	84
90	66	39	66	84	77

Table 1. Hydrologic and anaerobic conditions at wetland 4, stations 88, 89 and 90. 23 June-15 September, 1992.

VEGETATION

As the growing season progressed and the length of time soils were saturated increased, dryland plants began to die and wetland plants began colonizing the wet margins and interiors of the wetlands. Each of the wetlands have been flooded for differing amounts of time and each is unique in its floral composition.

Wetland 1 contained few wetland plants early in the growing season except for Typha latifolia. In midsummer, additional species were observed including Cyperus aristatus, Echinochloa crus-galli, Eleocharis coloradoensis, Potemogeton pectinatus and

P. pusillus. Most of the transplanted Scirpus paludosus, S. acutus and S. americanus have survived and are reproducing vegetatively and many have flowered and set seed. Several of the Scirpus paludosus that were transplanted as individual shoots and rhizomes now have 20 to 30 shoots and cover an 8 to 10 square meter area.

Sixty additional Scirpus acutus and 47 S. lacustris individuals were transplanted into standing water around the islands on the east side of wetland 1 in late July. All of these plants were eventually chewed off at or below the water line by ducks and geese and new shoots have yet to resprout.

Wetland 2 has changed little over the coarse of the season. Marsilea mucronata, Eleocharis macrostachya and E. coloradoensis are still the predominant wetland plants. However, a steady increase in Typha latifolia has been observed. This is probably due to the frequent drawdowns that have occurred at this wetland over the summer allowing Typha latifolia to germinate and grow on the exposed mudflats.

The emergent plant species that began colonizing wetland 3 early in the growing season have been subjected to continuous inundation since midsummer and have since died back. These species include Typha latifolia, Eleocharis macrostachya, E. coloradoensis and Persicaria lapathifolia. An increase in floating and submerged aquatic plants such as Ranunclulus sclerata, Potemogeton pectinatus and P. pusillus have been observed.

Most of the plants that were transplanted into wetland 3 in June have survived and of these Sparganium eurycarpum, Sagittaria latifolia, Hippuris vulgaris, and Scirpus paludosus are reproducing vegetatively. In July, 46 Scirpus acutus plants (shoots and rhizomes) were transplanted into deep water. The shoots of all of these plants were chewed off below the water line by ducks and geese and their survival is questionable. Scirpus acutus plants also began to germinate along the pond margins in midsummer, presumably from seeds broadcast in early June.

In wetland 4, Persicaria lapathifolia and Typha latifolia are the dominant emergent species. Scirpus acutus, S. paludosus and S. americanus, either from transplants or seeding, are also abundant along the shoreline. In the flooded basin, Potemogeton pectinatus, P. pusillus, P. gramineus and Marsilea mucronata are common.

Despite several drawdowns over the coarse of the growing season, wetland 5 remains devoid of all but a few wetland plant species. A few scattered individuals of Hordeum jubatum, Cyperus aristatus, Persicaria lapathifolia and Typha latifolia appear to be the only wetland plants present. This lack of wetland vegetation is possibly due to a dense layer of decaying upland vegetation that may be preventing seed germination by blocking sunlight.

Vegetation Classification (TWINSPAN)

Vegetation in all 121 plots was classified using "two way indicator species analysis", a divisive hierarchical classification technique of the computer program TWINSPAN. Only vegetation data is used in this analysis. 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 environmental factor determining the composition of stands along the study gradients. Within the gradient, it is the duration of inundation that 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 latifolia 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 and other wetland margin species.

The final classification is presented below and includes 8 community types. This classification is illustrated in Figure 12.

1. Potamogeton pectinatus - Potamogeton pusillus. This community type is dominated by pondweeds and is most common in wetland 4 where wetland plant seeds were dormant in the soils. This site was a natural wetland prior to wetland creation. These communities will spread through the study area to aquatic ecosystems in wetlands 1, 2, 3 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 3 and also occurs in 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 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 the next growing season.

4. Persicaria lapathifolia. This Eurasian annual plant species is widespread throughout the temperate zone of North America and comes to dominate wet and disturbed ponds and pond margins. It was robust at the Rocky Mountain Arsenal wetlands during 1991, but most likely its abundance will decrease as long-lived perennials, such as cattail and bulrush, come to dominate the wetland margins.

5. Sisymbrium altissimum - Typha latifolia. This community occurred during 1991 on pond margins that were wet during 1990 and dry in the early parts of 1991. These sites were wet enough during 1990 to kill most of the dryland plants, but a soil seed bank of Sisymbrium and Descurania spp. (two coarse annual mustards) germinated and proliferated during 1991. This community was abundant around wetland 3 in particular. Cattails have invaded

this community and we do not expect to see this community developed again.

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 within these stands 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.

Multivariate Community Gradient Analysis

Multivariate community gradient analysis was performed using the computer program CANOCO to identify the underlying structure of the vegetation data set and to determine environmental variables that most likely explain the floristic variation. The analyses use both species data and environmental data from the study plots. Figure 13 is a biplot of study plots and environmental factors. The horizontal axis is highly correlated with the environmental

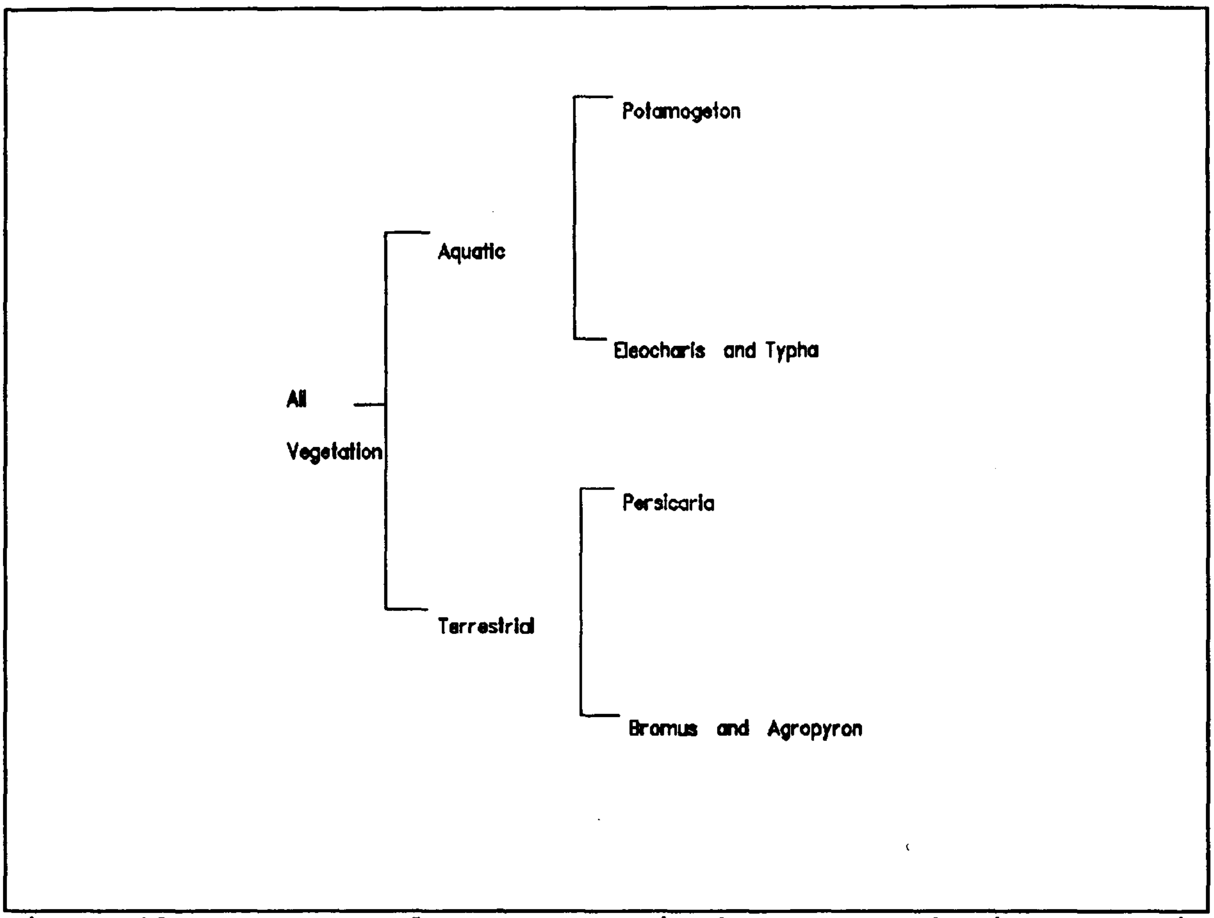


Figure 12. TWINSPAN cluster analysis dendrogram showing the main vegetation types occurring in the study area plots.

factors nda5, nda10 and nda20 (number of days anaerobic at 5, 10 and 20 cm soil depths), ndf (number of days flooded), mwd (maximum water depth) and awd (average water table depth). Thus, the first axis is highly correlated to the water table gradient, being wettest on the right and driest on the left. On the left side of the biplot, nnd (number of days not flooded) is highly correlated. The vertical axis is explained by nwl (whether or not a wetland is natural).

Figure 14 is a species ordination produced by CANOCO. The same environmental gradients are used to restrain the ordination axes. Wettest sites are on the right, and driest sites are on the left. The aquatic plant species Chara spp., Potamogeton pusillus, P. pectinatus, Eleocharis palustris are shown on the right, while dryland species such as Ambrosia psilostachya occur on the left. The vertical axis splits the ordination space into wetland plants on the right and dryland plants on the left.

The vertical axis is mostly explained by whether a wetland is a preexisting natural wetland basin, or whether it has been recently created. Natural wetlands occur at the bottom of the ordination, while newly created wetlands are at the top. Clearly, species such as Eleocharis palustris, E. parvula, Potamogeton spp. and Persicaria lapathifolia are most common in restored wetlands and most likely persisted as dormant seed in the soil, germinating when the basins were filled with water. By contrast, species of Chara have colonized the aquatic zone of newly created wetland basins, and Lemna minor was introduced only to wetland 3, a newly created wetland basin. In addition, the annual weeds Descurania sophia, and Sisymbrium altissimum were abundant on the drawdown shores of wetland 3. Thus, newly created wetlands had only one common natural invading aquatic plant species, Chara.

The plants on the dry (left) side of the ordination diagram have little to do with the water table gradient or whether the basins are remnants or newly created.

When the data set is analyzed as a whole, it is evident that the wetlands are quite different floristically. Many plant species are limited to the restored wetland basins and it is these basins that provide the greatest potential for wetland development at the Rocky Mountain Arsenal. The growth of mature aquatic plant communities in these natural wetland basins emphasizes the overwhelming importance of the soil seed bank for rapid wetland development. Other environmental factors, such as treatments used in the study plots (pulling cattails and planting species) were not statistically significant during 1992. We predict that by the end of 1993, the importance of the treatments will be nearly as great as the pre-existing soil seed bank for determining the patterns of species occupying the wetlands.

Patterns of Plant Species Richness

The computer program CANOCO was used to determine the patterns of plant species richness in study plots and their environmental correlates. Figure 15 shows species richness (each circle identifies a plot with larger circles indicating more species in that plot). Clearly the largest circles are on the left side of the axis and the smallest circles are on the far right. The axes are identical to those described previously and represent a hydrologic gradient, being wettest on the right and driest on the left. Thus, drier plots support more species. This relationship is also shown in Figure 16 which plots species richness vs. number of days of inundation. This analysis indicates that few plant species are adapted to the stressful aquatic and wetland environment, and a particular wetland plot may support few species.

Weighted Average Index Analysis

The organization of plant communities along a gradient can be examined using weighted averages. Weighted averages have been used to designate wetlands based solely on plant communities by ranking stands based on the composition of plant species with affinities to wetlands.

The United States Fish and Wildlife Service (USFWS) Wetland Classification System (Cowardin et al. 1979) requires the identification of key wetland indicator plant species. These plant species are ranked according to their fidelity to wetlands and range from upland to obligate wetland with varying degrees of association with wetlands in between (Reed 1988) (Table 2).

Category	Percent probability of occurrence in wetlands
Obligate wetland (OBL)	>99
Facultative wetland (FACW)	67-99
Facultative (FAC)	34-66
Facultative upland (FACU)	1-33
Upland (UPL)	<1

Table 2. National wetland plant list categories used by the USFWS to group plant species in accordance with their fidelity to wetlands.

Weighted averaging assigns each species within a stand a numerical weight based on the wetland indicator status for that particular species ranging from 1 (obligate) to 5 (upland). The percent cover of each species is multiplied by its assigned weight and divided by the total percent cover for the entire stand. Using this method, stands receive scores ranging from 1.0 (all obligate species) to 5.0 (all upland species).

The indicator status of each station in wetland 4 is shown in figure 15. This graph shows that there is very little gradation from dry to wet; a site is either a dryland site or it is a wetland site. This lack of a transition zone or edge is due to the water table dropping quickly at the margins of the wetland. There are few sites where the water table is slightly below the soil surface for extended periods of time.

DISCUSSION

Research efforts in 1993 will include the continued monitoring of hydrology, soils and vegetation at the 5 wetlands. Relatively little is known about the patterns of species colonization and community structure in newly created wetlands or the success of various methods of establishment. Information obtained from this research will be invaluable in determining the most successful methods for creating new wetlands and restoring degraded wetlands.

In addition, a plant competition study will be carried out between Typha latifolia and other species to determine the influence of this species on community structure. It is hypothesized that Typha latifolia is a dominant competitor that ultimately determines the structure of wetland plant communities in created and restored wetlands. This study will include a field experiment in one of the wetlands supplemented by a greenhouse study under controlled environmental conditions.

We would also like to examine other sites on the Arsenal to evaluate their potential for future wetlands creation. As discussed above, natural wetland basins typically provide the highest potential for successful wetlands creation.

Natural wetlands undoubtedly occurred on the Arsenal prior to agricultural development in the early 1900's. Many of these wetlands were subsequently drained and converted to cropland or rangeland. This study would entail locating prospective sites from aerial photographs and topographic maps and sampling the soil seed bank. A small soil sample would be collected and subjected to different hydrologic regimes in an attempt to get dormant seeds to germinate.

FIGURE 1. WETLAND 1, WEST-EAST PROFILE

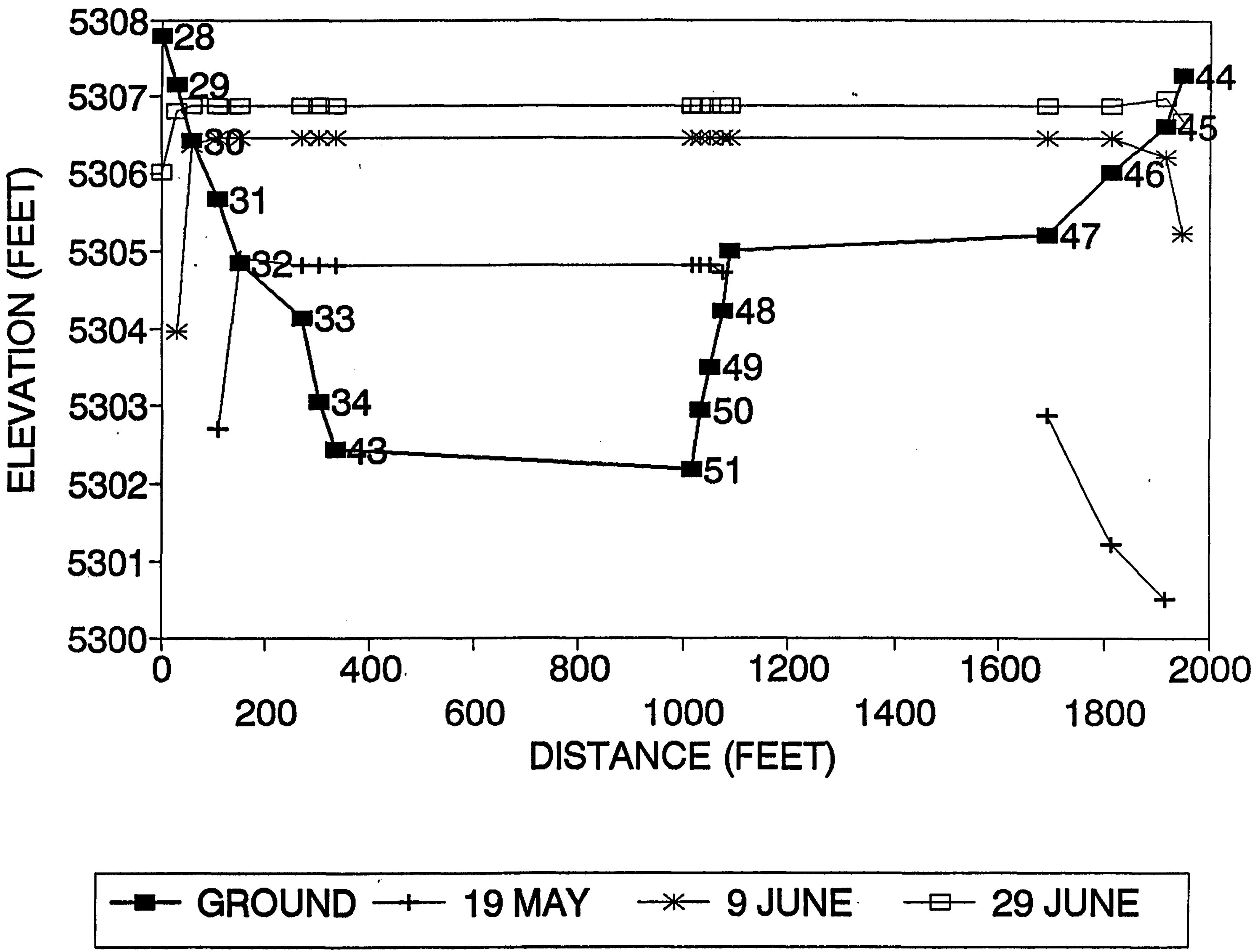


FIGURE 2. WETLAND 2,NORTH-SOUTH PROFILE

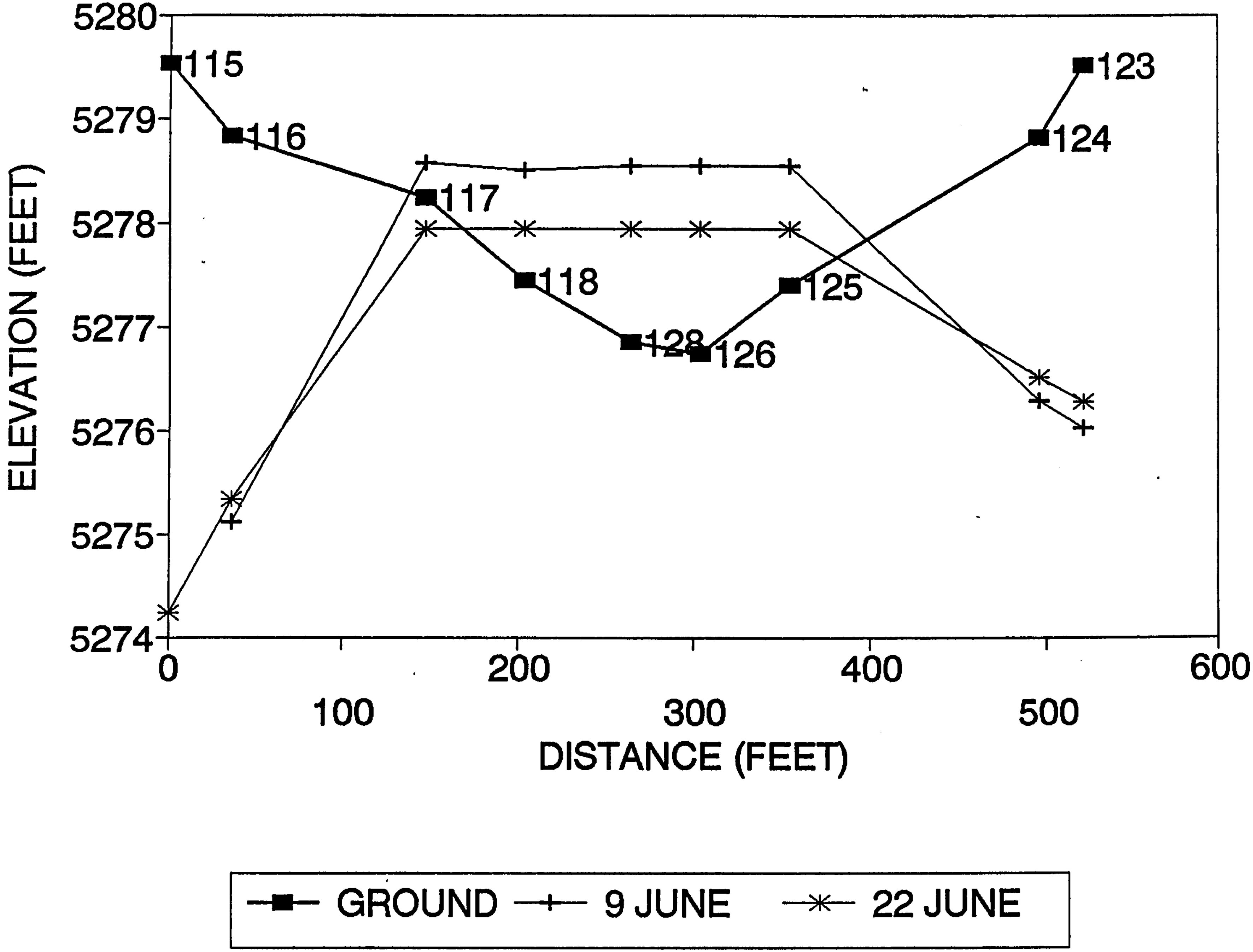


FIGURE 3. WETLAND 3,EAST-WEST PROFILE

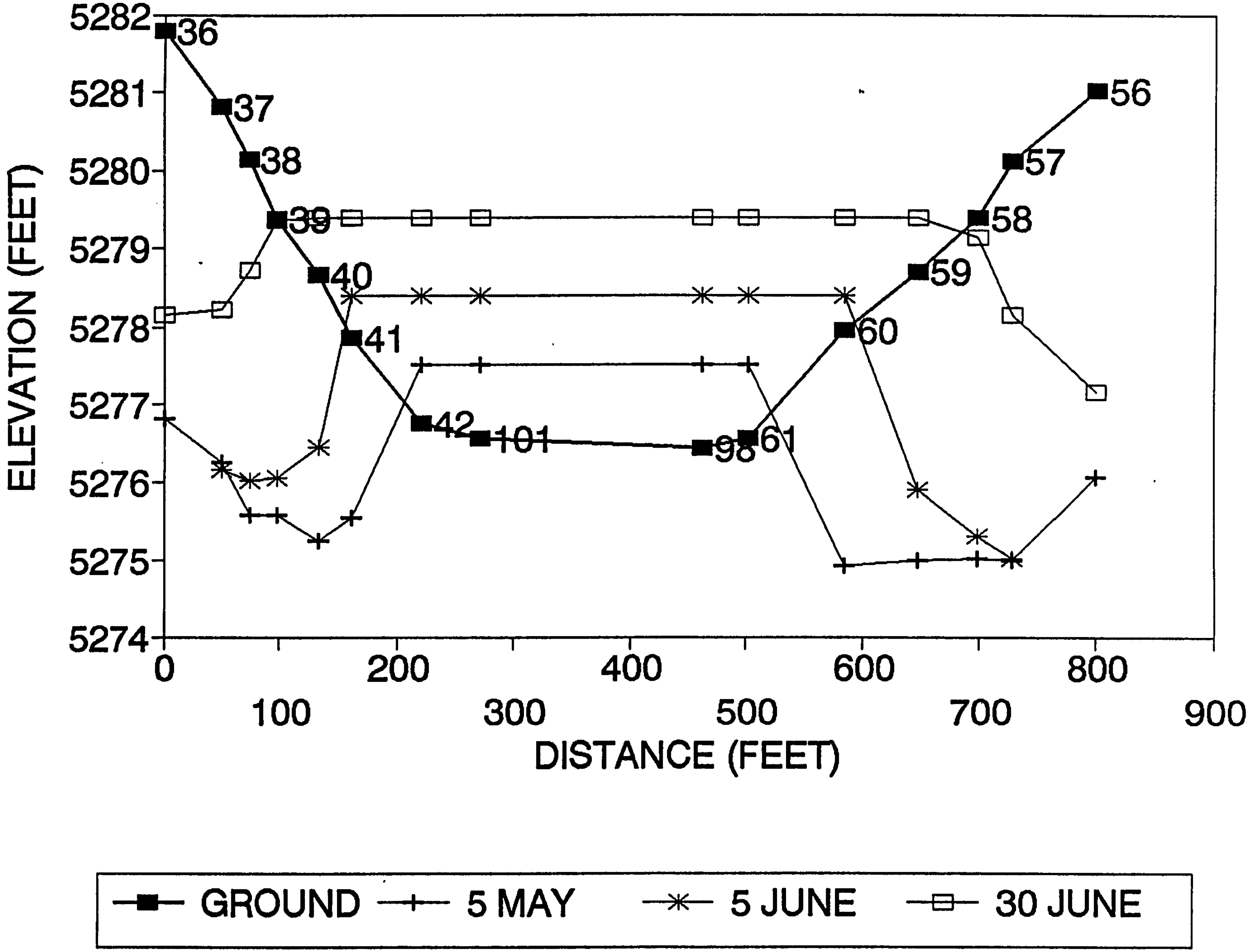


FIGURE 4. WETLAND 3, SOUTH PROFILE

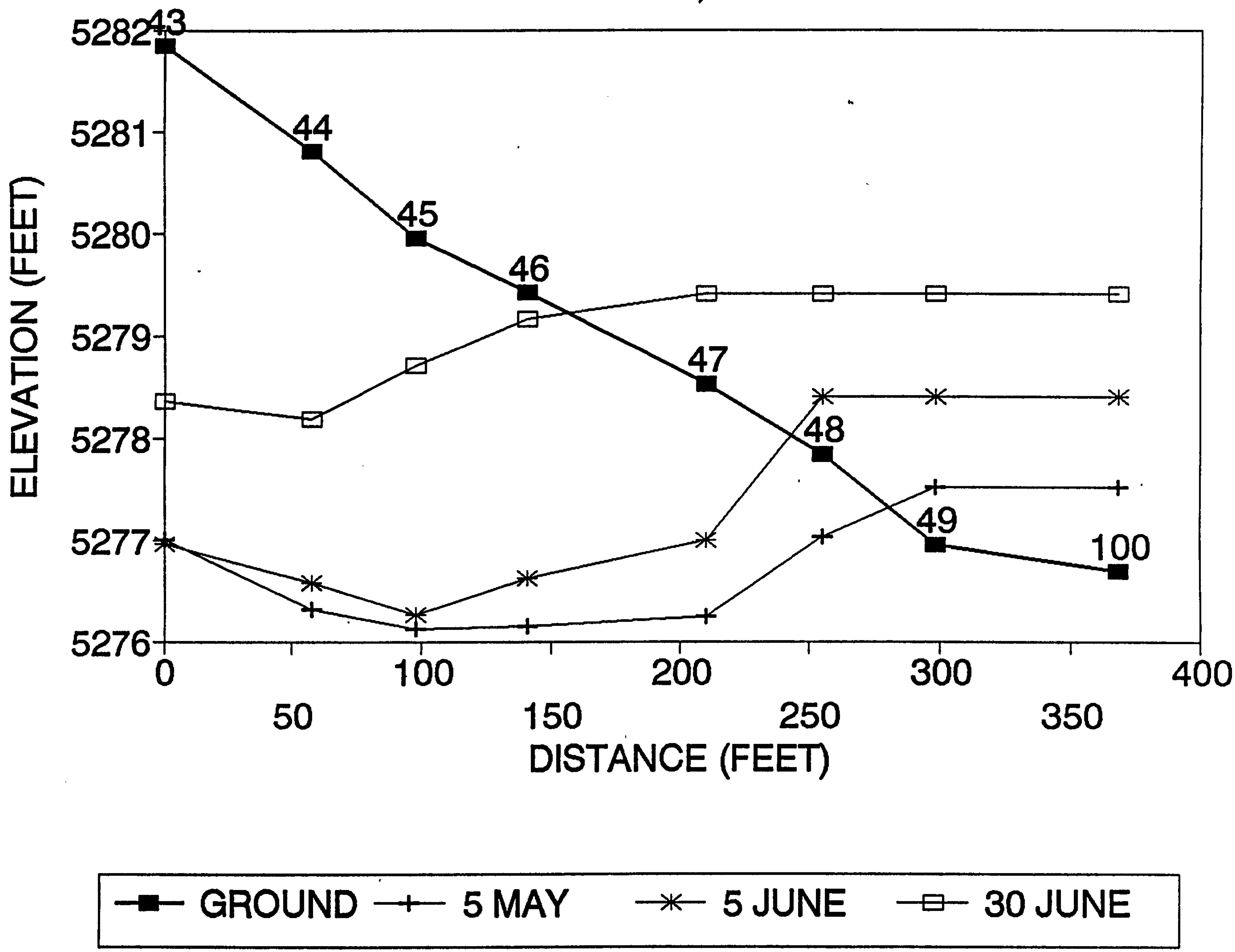


FIGURE 5. WETLAND 4,SOUTH-NORTH PROFILE

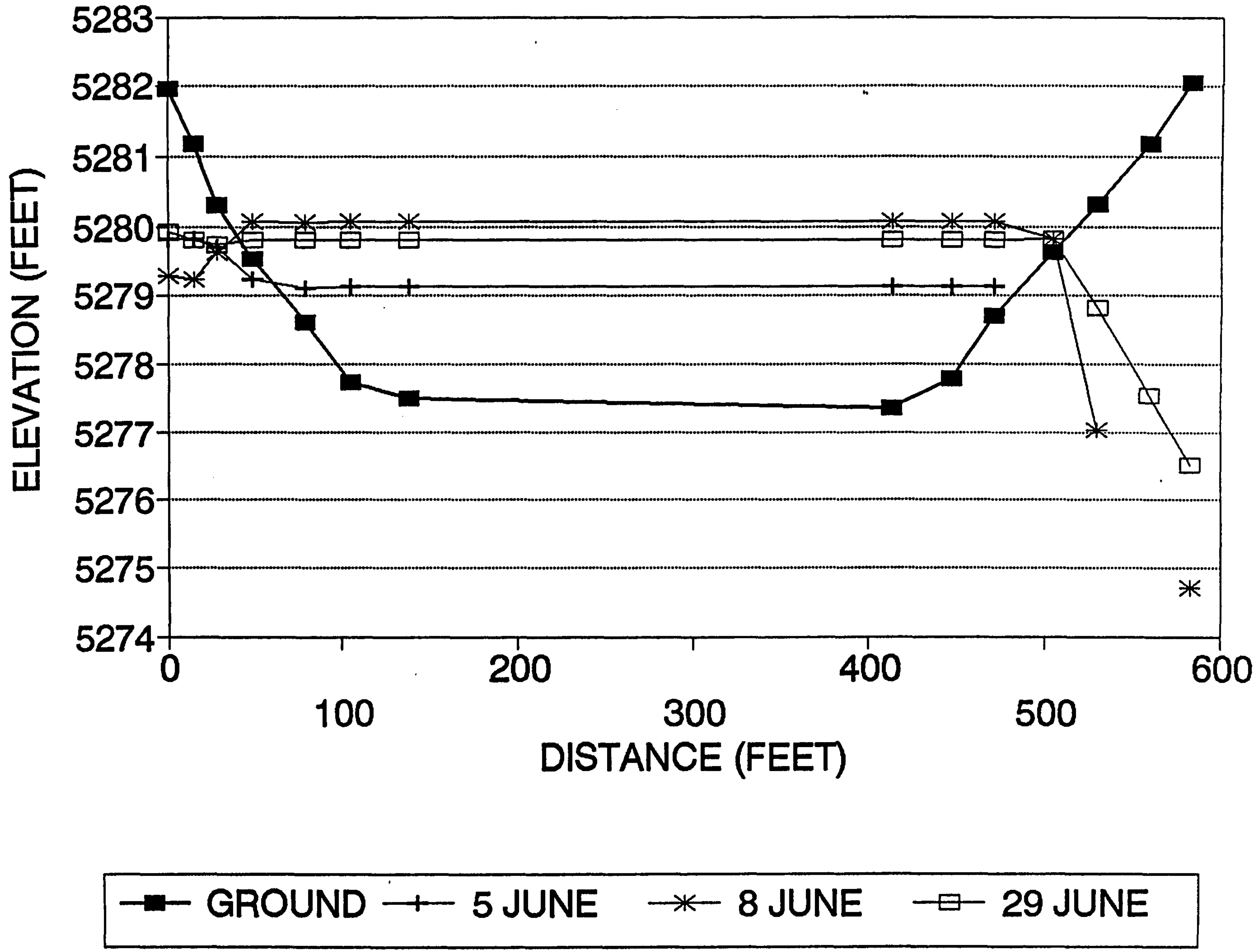
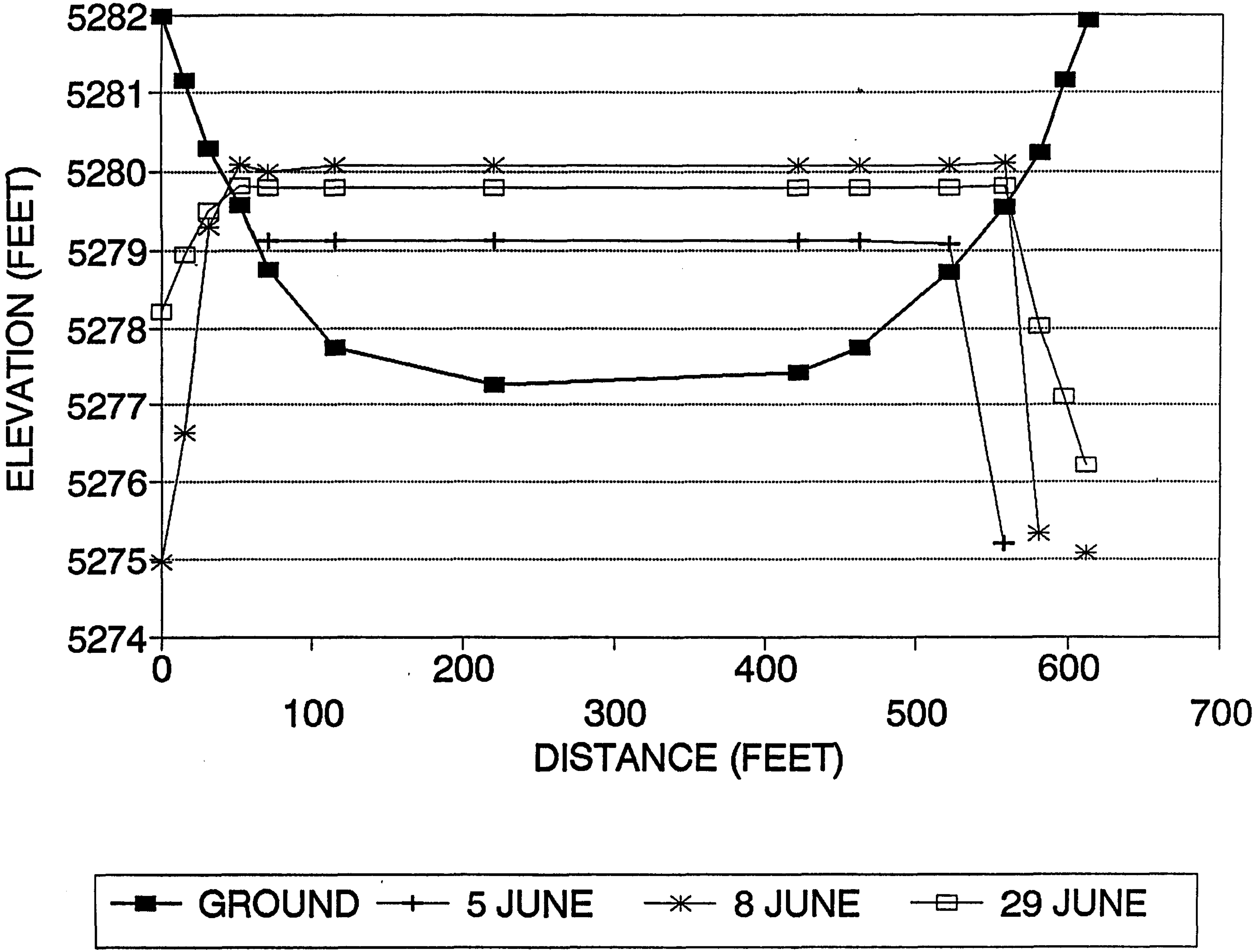


FIGURE 6. WETLAND 4, WEST-EAST PROFILE



30

FIGURE 7. WETLAND 5, SOUTH PROFILE

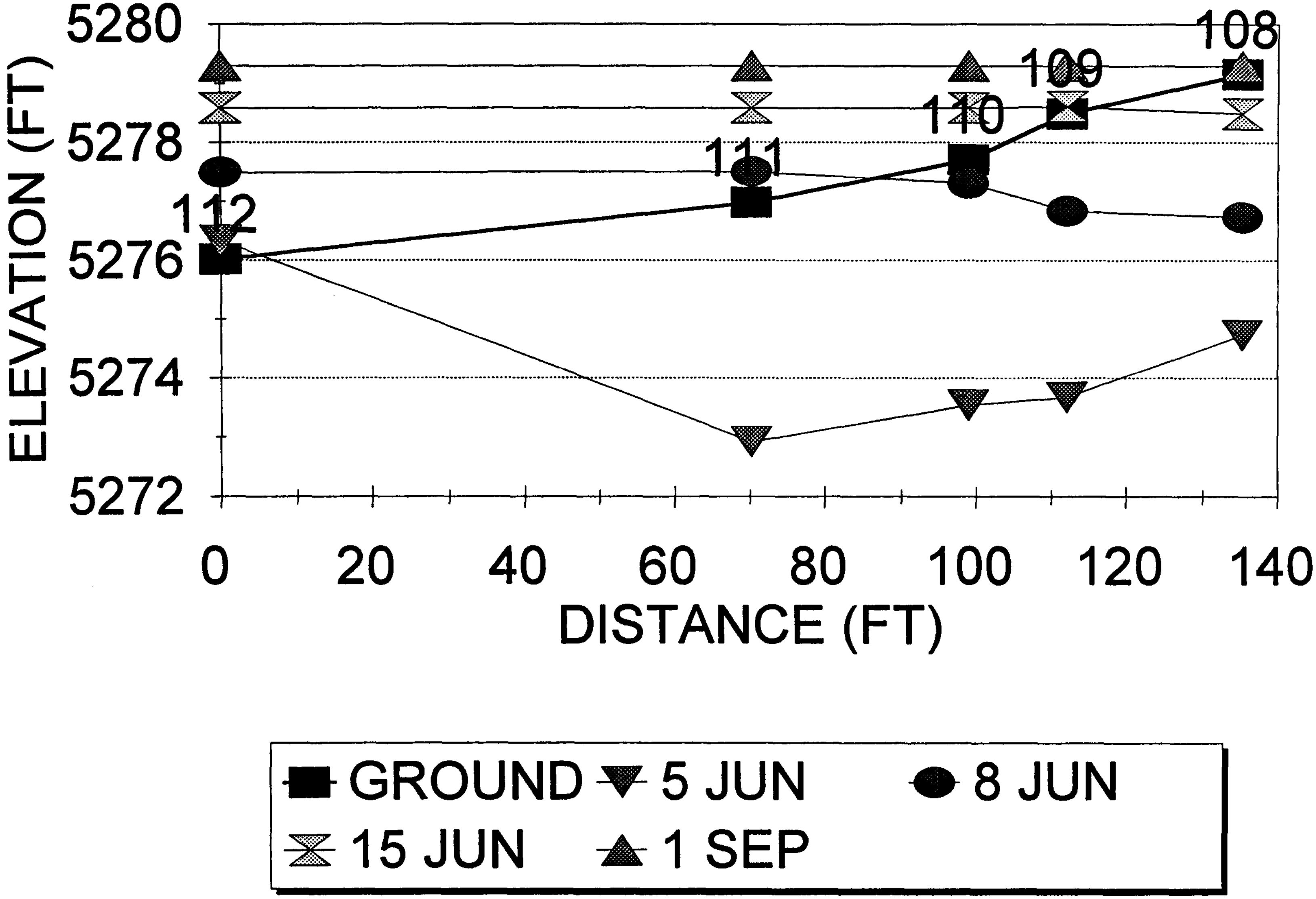
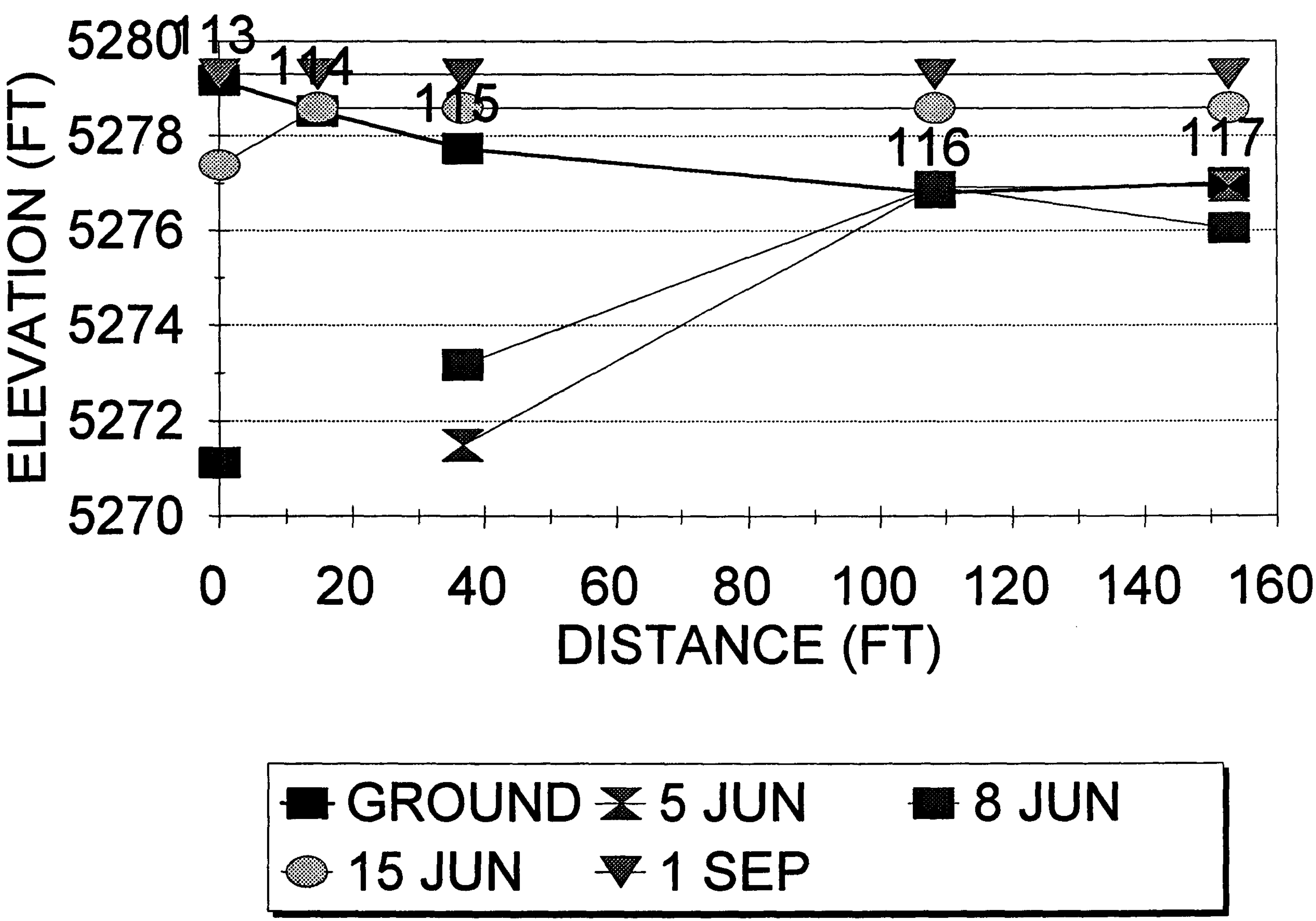


FIGURE 8. WETLAND 5, WEST PROFILE



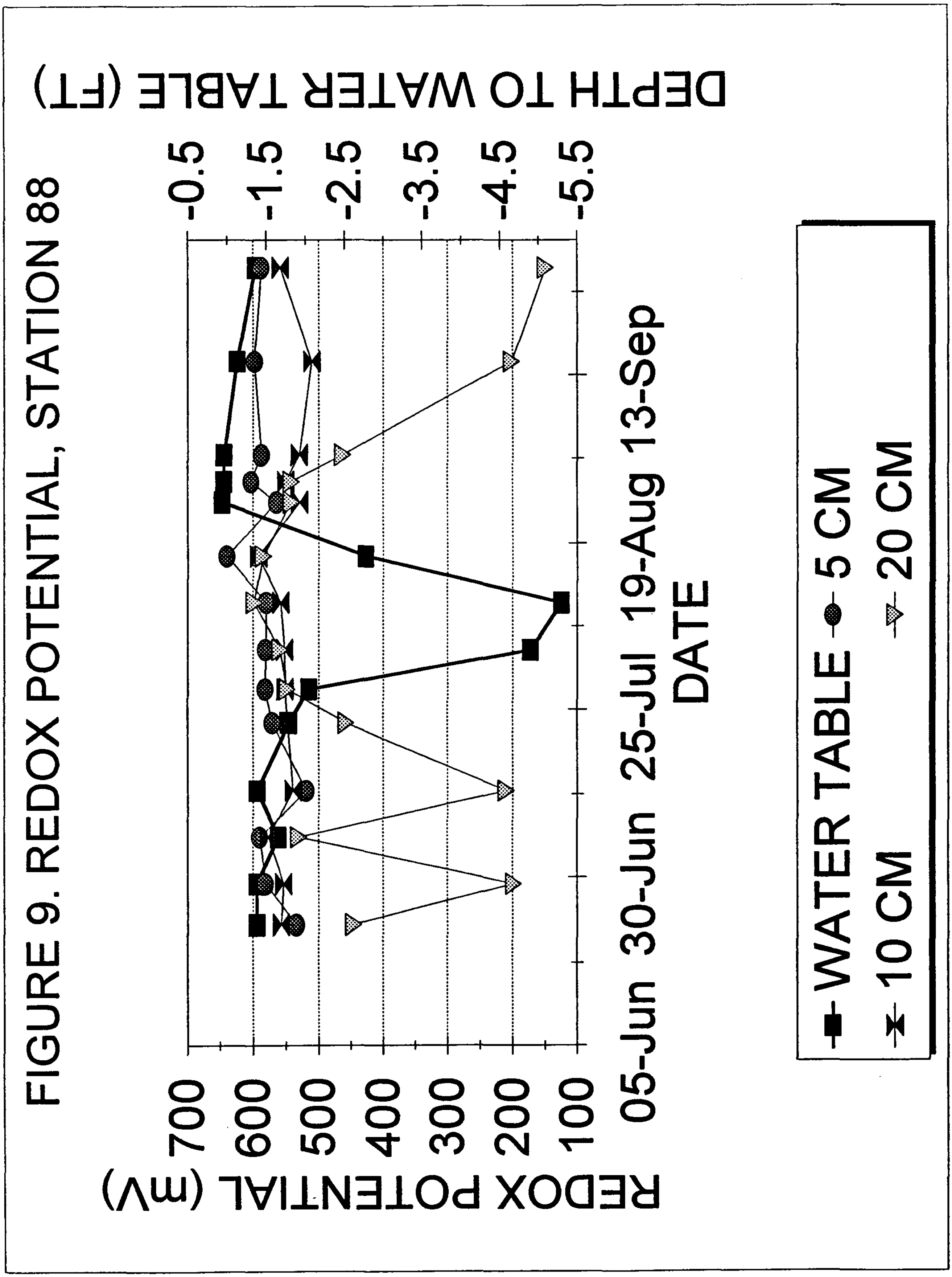


FIGURE 9. REDOX POTENTIAL, STATION 88
REDOX POTENTIAL (mV)
700
600
500
400
300
200
100
DEPTH TO WATER TABLE (FT)
-0.5
-1.5
-2.5
-3.5
-4.5
-5.5
05-Jun 30-Jun 25-Jul 19-Aug 13-Sep
DATE
WATER TABLE
5 CM
10 CM
20 CM

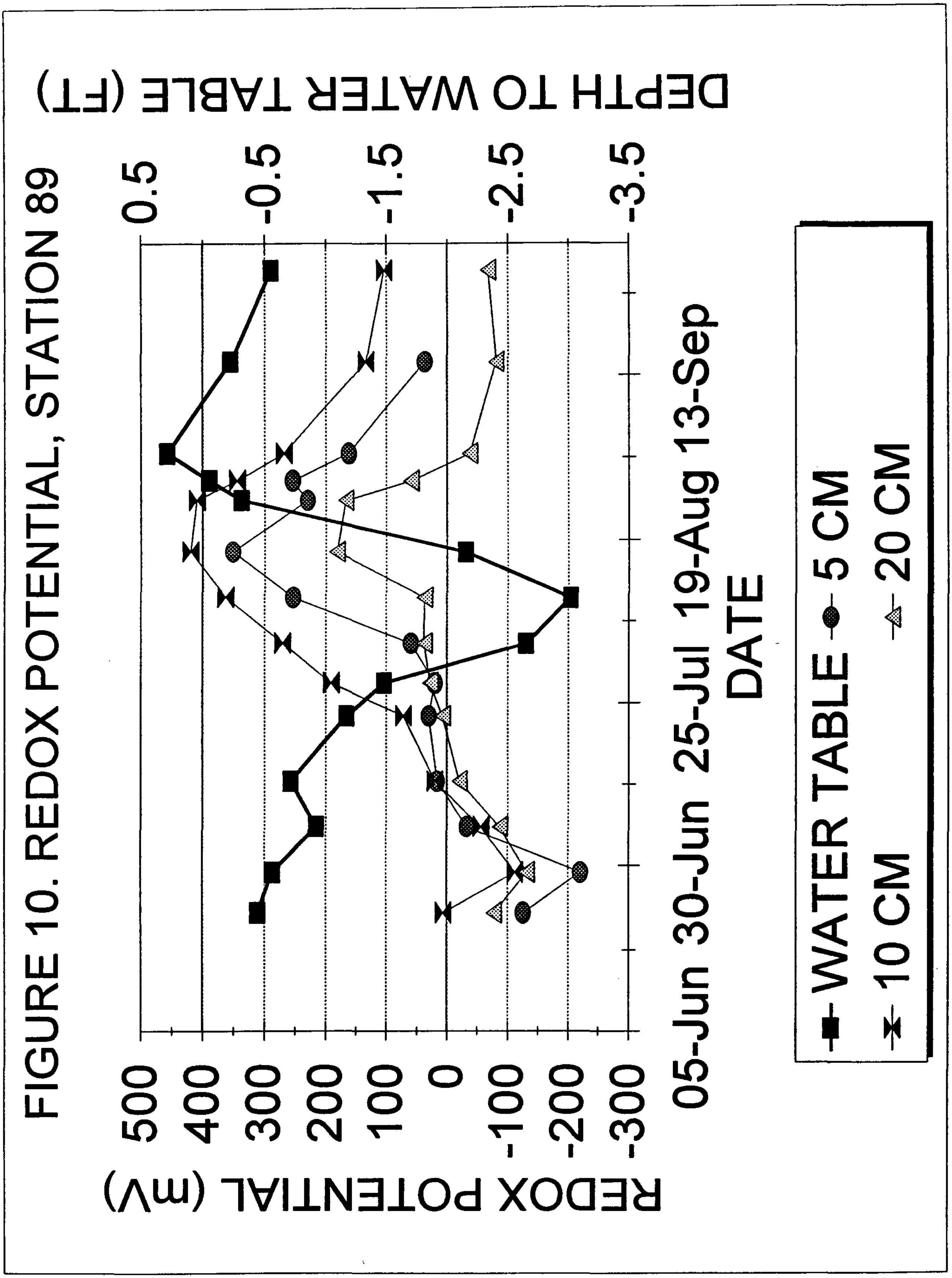
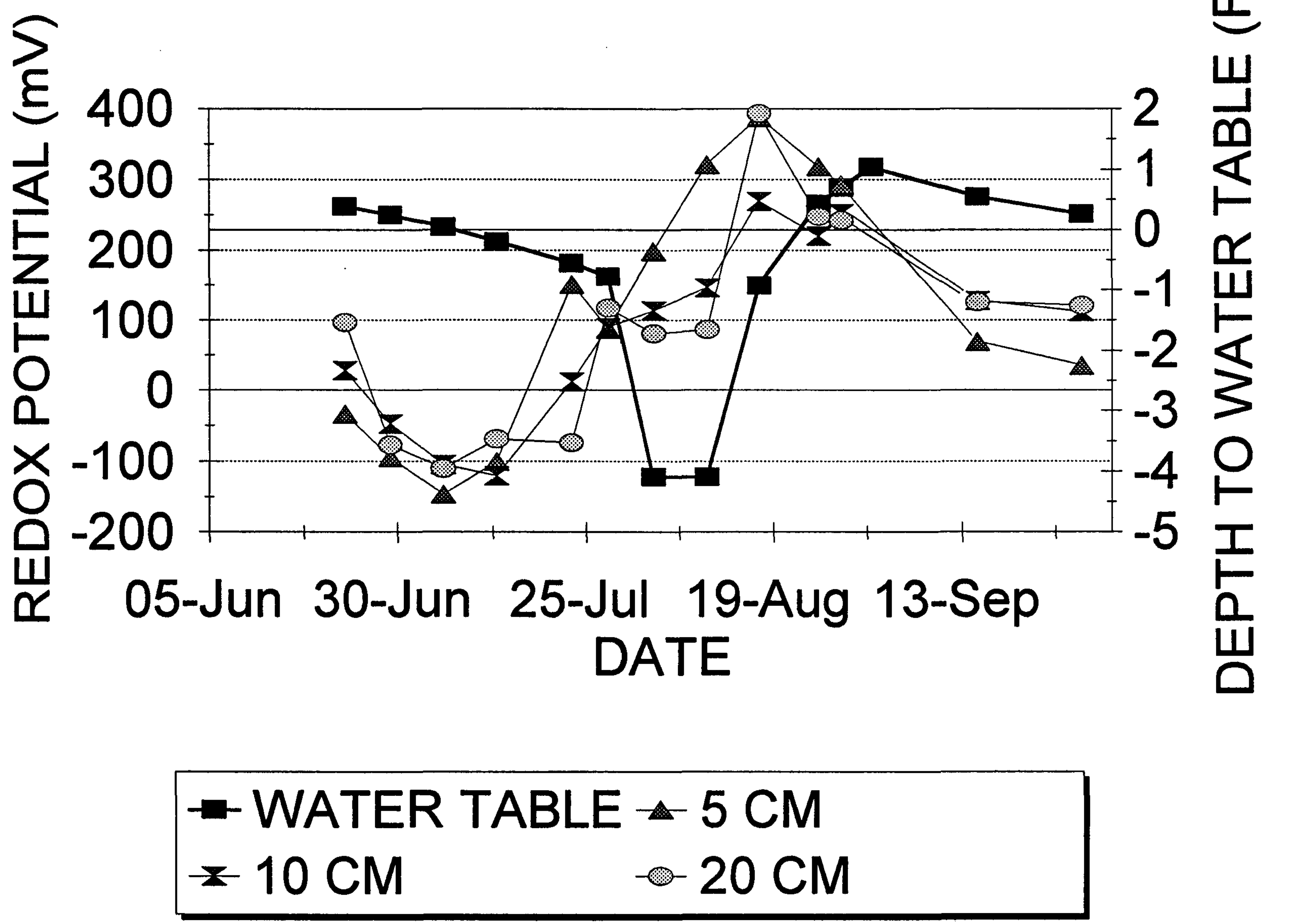


FIGURE 10. REDOX POTENTIAL, STATION 89

FIGURE 11. REDOX POTENTIAL, STATION 90



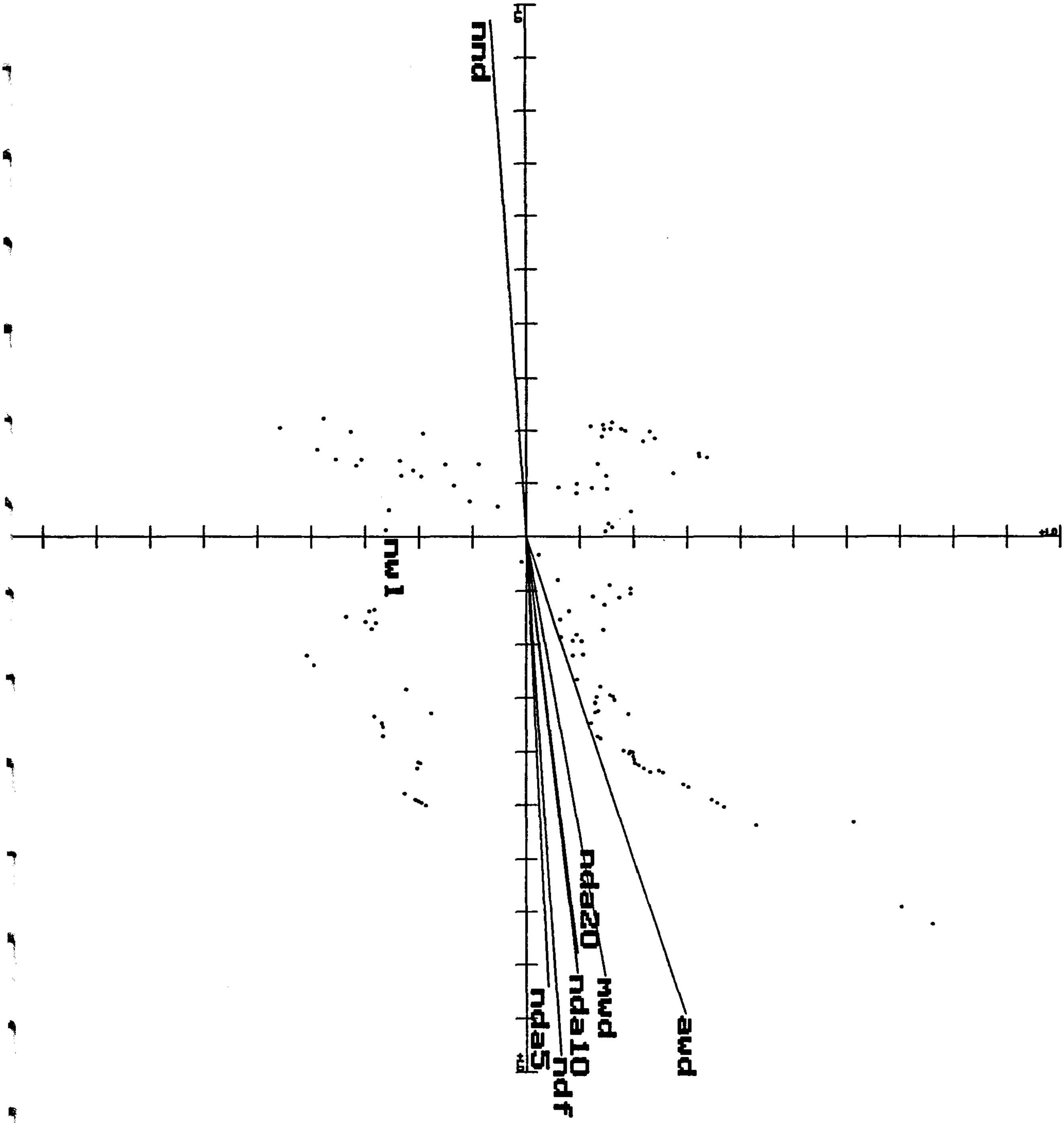


Figure 13. Biplot based on canonical correspondence analysis of study plots and environmental factors. See text for explanation of abbreviations.

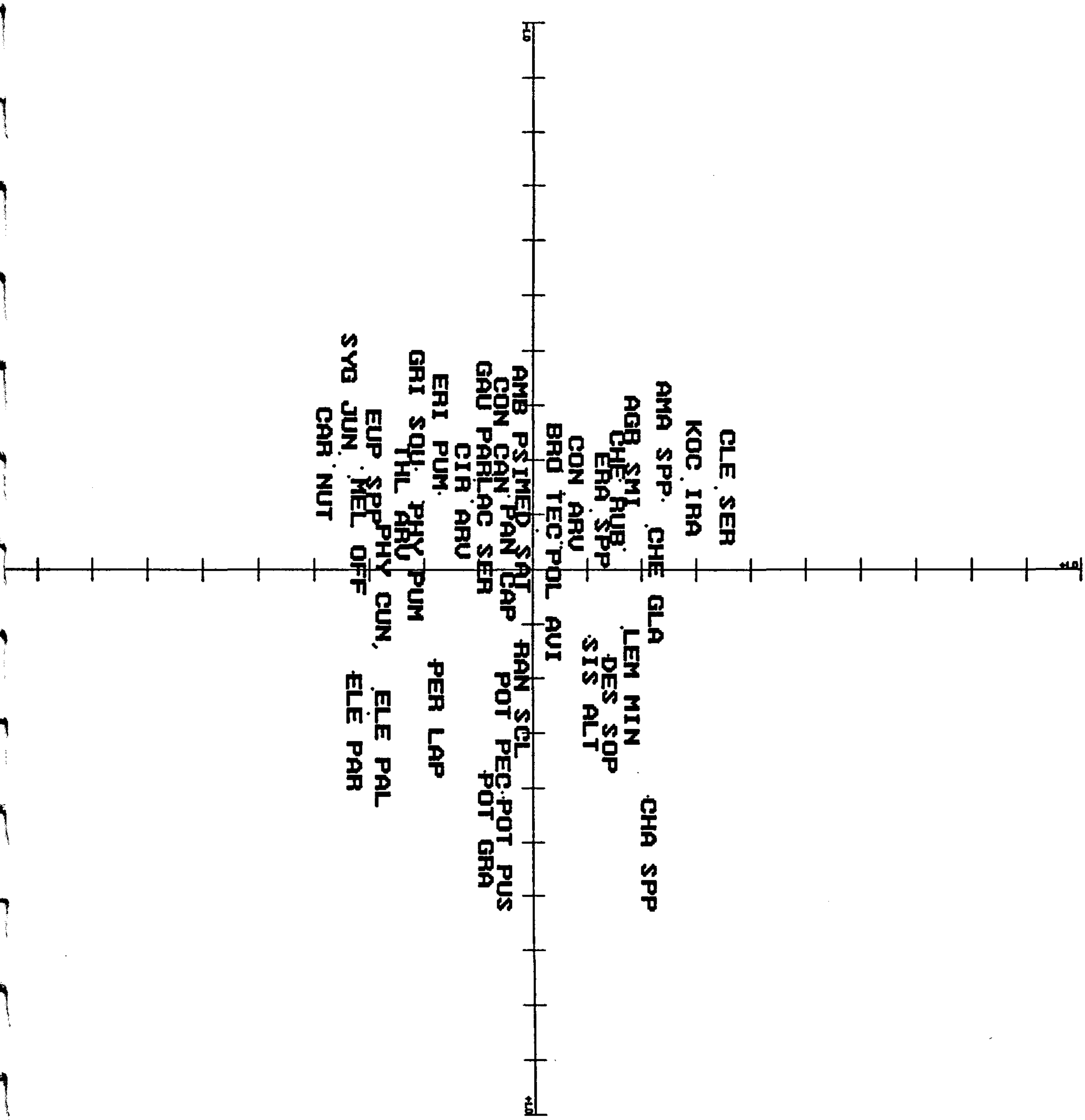


Figure 14. Ordination diagram based on canonical correspondence analysis of species and environmental factors. Wettest sites are on the right and driest sites are on the left.

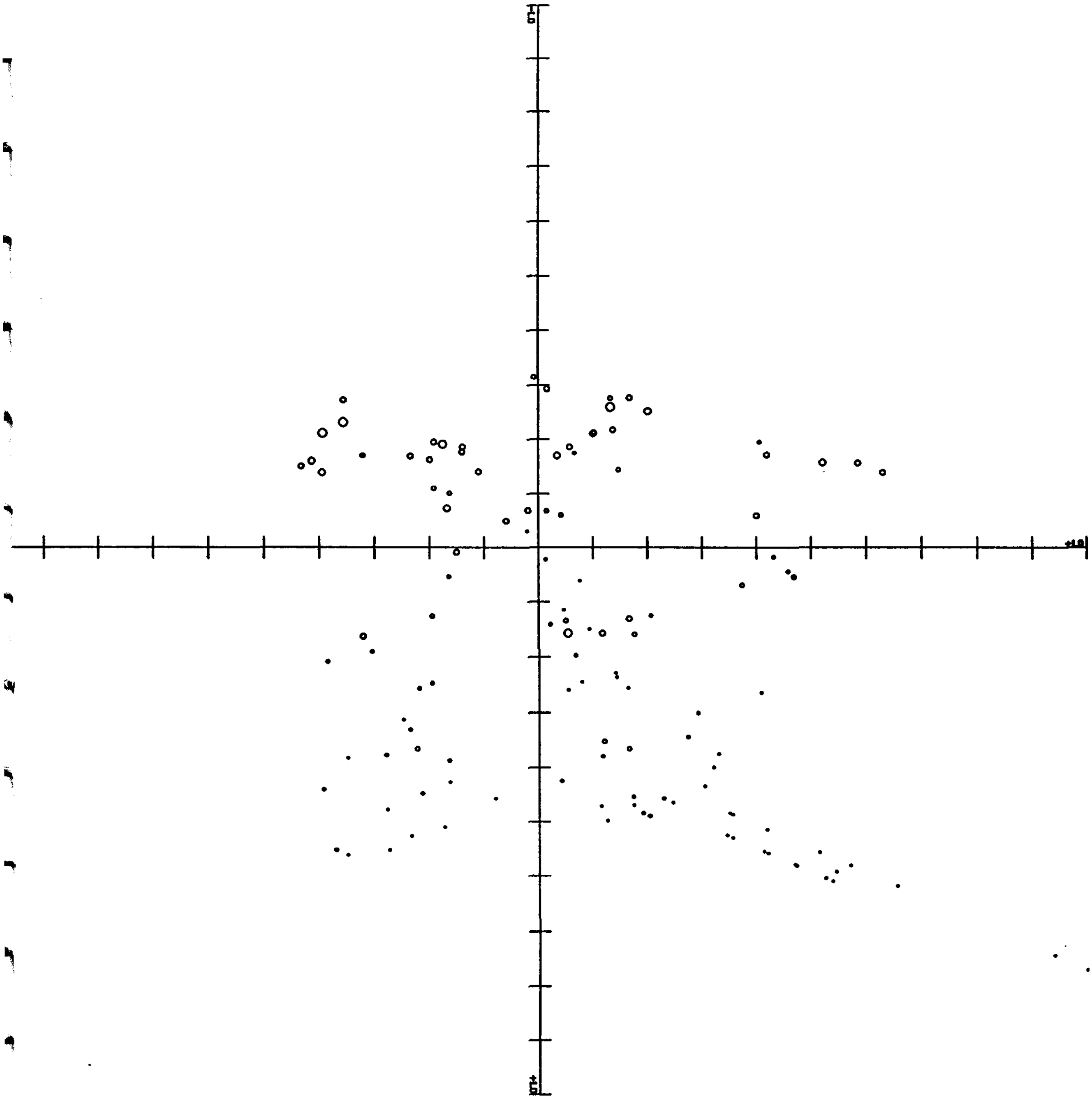


Figure 15. Canonical correspondence analysis of species richness. Larger circles indicate more species.

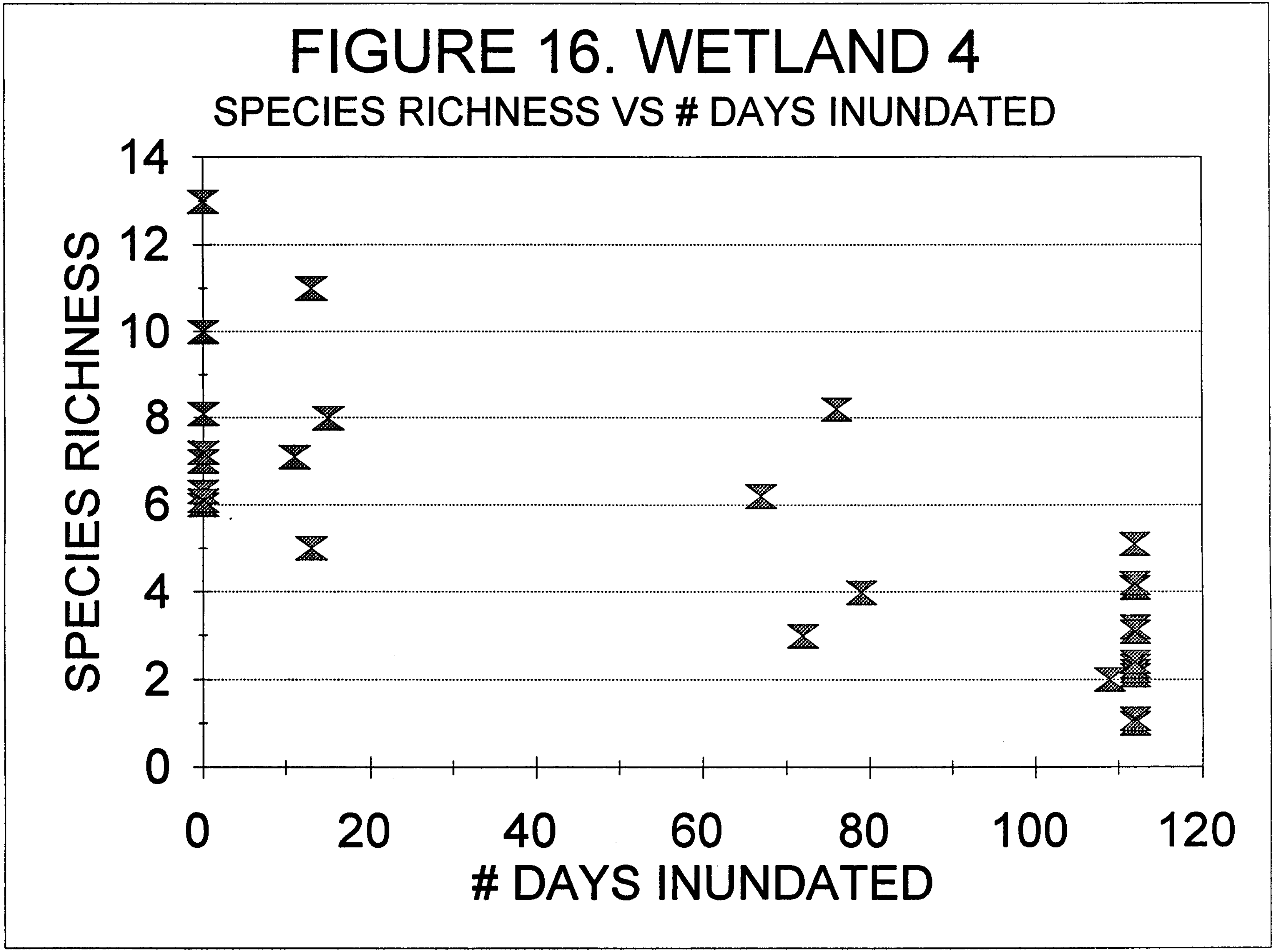


FIGURE 16. WETLAND 4
SPECIES RICHNESS VS # DAYS INUNDATED
SPECIES RICHNESS
14
12
10
8
6
4
2
0
0
20
40
60
80
100
120
DAYS INUNDATED

BADGERS ON THE ROCKY MOUNTAIN ARSENAL

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14 May 1992

Abstract: Nineteen badgers (*Taxidea taxus*) were captured on the Rocky Mountain Arsenal (RMA) using Woodstream Softcatch® traps and live snares. This represents a minimum density estimate of 0.27 badgers per km^2. Radio transmitters were placed in the abdomens of 10 badgers and a lower premolar was extracted for cementum annuli analysis for age determination. Adult badgers (n = 12) averaged 2.3 years old. Six badgers were radio-located from October 1990 through March 1991, but sample sizes were inadequate to generate home range estimates.

Key words: badger, cementum annuli, Colorado, home range, implant, radiotelemetry, *Taxidea taxus*.

In a cooperative agreement between United States Fish and Wildlife Service and Colorado State University, a field study of coyotes (*Canis latrans*) on the Rocky Mountain Arsenal (RMA) began in May 1990. Coyotes and badgers were captured in traps set for coyotes. This report summarizes data collected on badgers on the RMA.

STUDY AREA

The Rocky Mountain Arsenal (RMA) comprises 70 km^2 at the northern boundary of Stapleton International Airport in Commerce City, Colorado. Average elevation is 1600 m with maximum topographical relief of approximately 60 m.

A variety of grasses and forbs are found on the RMA including cheatgrass (Bromus tectorum), crested wheatgrass (Agropyron cristatum), blue grama (Bouteloua gracilis), perennial summercypress (Kochia americana), sand sagebrush (Artemisia filifolia), and rubber rabbitbrush (Chrysothamnus nauseosus). Trees, such as plains cottonwood (Populus sargentii), New Mexican locust (Robinia neomexicana), peach-leaved willow (Salix amygdaloides) and Russian-olive (Elaeagnus angustifolia) are found in localized, dense stands.

A large variety of birds including lark buntings (Calamospiza melanocorys) and western kingbirds (Tyrannus verticalis) are abundant during summer, whereas ferruginous hawks (Buteo regalis) and bald eagles (Haliaeetus leucocephalus) are abundant during winter on RMA. White-tailed deer (Odocoileus virginianus), mule deer (Odocoileus hemionus), black-tailed prairie dogs (Cynomys ludovicianus), black-tailed jackrabbits (Lepus californicus), coyotes, and badgers (Taxidea taxus) are common on the area.

Climate is characterized by low humidity, abundant sunshine, and temperatures averaging -1° C in January and 23° C in July (Natl. Oceanic and Atmos. Adm. 1990). Precipitation averages 37 cm annually with the majority falling between April and July.

METHODS

Snares (Nellis 1968) and Woodstream Softcatch® traps (Linhart et al. 1986) with attached tranquilizer tabs (Balser 1965, Linhart et al.

1981) were used to capture badgers. Carman's Distant Canine Call, (Russ Carman, New Milford, Pa.), Fatty Acid Scent (Pocatello Supply Depot, Pocatello, Id.), and W-U lure with 10% Trimethylammonium Decanoate (J-T Eaton & Co. Inc., Twinsburg, Oh.) were used as scents to attract animals to traps. The 3 scents were used at approximately the same number of trap locations during July and August of 1990. We occasionally used Carman's Final Touch and Carman's Gland lure during September to November 1990. To help exclude small non-target animals, tension of the trap pan was adjusted to approximately 2.0 kg (Linhart et al. 1981) using a trap pan-tension scale ("H.T.'s Trap-pecker®", Rocky Mountain Wildlife Products, Laporte, Colo.).

Badgers were tranquilized with Ketamine hydrochloride before handling. All badgers were fitted with a Nasco standard Roto-tag® (Nasco, Fort Atkinson, Wis.) and selected individuals received 167 mHz model 17 radiotelemetry implants (Advanced Telemetry Systems Inc., Isanti, Minn.) weighing 80 g. The Roto-tag® was attached to the right ear of males and the left of females. A lower premolar was extracted for cementum annuli age analysis (Crowe and Strickland 1975).

Radiotelemetry signals were monitored with a model 2000 programmable scanning receiver (Advanced Telemetry Systems, Inc., Isanti, Minn.) attached to a vehicle-mounted dual 4-element null-peak yagi antenna system. Badgers were located using 2 compass ("KB-20", Suunto, Espoo, Finland) bearings from 2 of 181 receiving stations. Density was calculated by dividing the size of the RMA by the number of captured badgers.

RESULTS

We captured 6 juvenile (3 females and 3 males) and 13 adult (6 females and 7 males) badgers in 3,920 trap and 100 snare nights. Thirteen of 19 badgers were captured in traps scented with Carman's Distant Canine Call, 3 in traps scented with W-U lure, 1 in a trap scented with Carman's final touch, 1 in a trap scented with Carman's gland lure and 1 was snared. Although trapping effort was unequal (2,293 trap nights in July and August and 1,627 nights from September through January), sixteen of 19 badgers were captured during July and August. Ten badgers were implanted with radiotelemetry transmitters. Adult badgers averaged 2.3 (range 1 to 7) years old. Juveniles averaged 5.6 (females 5.3 and males 5.9) kg, whereas adults averaged 7.0 (females 6.7 and males 7.3) kg (Table 1). We calculated a minimum density estimate of 0.27 badgers per km^2.

Two badgers died during the study; 1 was road-killed and 1 probably was killed by coyotes. We obtained 50 (range 2 to 12) telemetry location estimates on 6 badgers. Sample sizes were inadequate to generate home range estimates.

Discussion

Most badgers were captured during July and August, which coincided with their breeding season (Messick and Hornocker 1981). The large proportion of badgers captured during July and August also may have been related to readily capturing badgers that had not been captured before and difficulty in recapturing them resulting from trap shyness (Eberhardt 1969).

Density estimates of 2.6 badgers per km^2 (Lindzey 1971) and up to 5 resident badgers per km^2 (Messick and Hornocker 1981) have been reported, suggesting 0.27 badgers per km^2 on the RMA is low and likely is underestimated.

Radio implants have been used successfully in badgers (Minta and Mangel 1989), and did not seem to adversely effect the badgers on the RMA. We encountered problems with signal reception due to the badgers' fossorial habits, and possibly lowered signal strength from both body absorption and a shortened-coiled antenna. Radio signals did not transmit greater than approximately 1 km, with strong signal reception at distances of < 0.5 km.

MANAGEMENT RECOMMENDATIONS

In future studies to capture and mark badgers, trapping may be most successful during July and August using traps scented with Carman's Distant Canine Call. Radio telemetry signals may be limited if transmitters are implanted.

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Table 1. Badger ages and weights on the Rocky Mountain Arsenal from July 1990 through March 1991.

Badger	Sex	Age	Date Captured	Weight (Kg)	Number of locations
167.940	F	3	Jul 90	6.1	2
167.898	M	1	Jul 90	4.5	4
167.977[a]	M	Adult	Jul 90	7.8	-
167.957[a]	F	Juvenile	Jul 90	4.3	-
167.919	M	2	Jul 90	9.1	11
167.621	M	1	Aug 90	6.7	9
167.957[b]	F	2	Aug 90	8.0	-
167.326	M	2	Oct 90	9.3	12
167.426	F	0	Oct 90	5.6	12
167.290	M	0	Oct 90	6.7	-
tag 32	M	3	Jul 90	8.6	-
tag 33	M	7	Jul 90	8.6	-
tag 34[a]	M	Juvenile	Jul 90	5.9	-
tag 35	M	0	Aug 90	5.7	-

[a]Age determined by badger size and tooth eruption.

[b]transmitter reused.

Table 1. Continued.

Badger	Sex	Age	Date Captured	Weight (Kg)	Number of locations
tag 36	F	2	Aug 90	6.8	-
tag 41	F	2	Aug 90	6.1	-
tag 42	F	1	Aug 90	6.4	-
tag 43	F	1	Aug 90	6.8	-
tag 59	F	0	Nov 90	5.9	-

COYOTE HOME RANGE ESTIMATES
ON THE ROCKY MOUNTAIN ARSENAL

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14 May 1992

Abstract: Seventeen coyotes (*Canis latrans*) were captured on the Rocky Mountain Arsenal (RMA) using Woodstream Softcatch® traps and live snares. Radio transmitters were placed on all coyotes and a lower premolar was extracted to determine age by analysis of cementum annuli. Adult coyotes (n = 7) averaged 3.3 years old. Thirteen coyotes were radio-located from November 1990 through March 1991 to generate home range estimates. Home ranges averaged 6.9 km^2 (SE = 1.0) for resident and 22.5 km^2 (SE = 5.4) for transient coyotes.

Key words: *Canis latrans*, cementum annuli, Colorado, coyote, home range, McPAAL, radiotelemetry, resident, transient.

In a cooperative agreement between United States Fish and Wildlife Service and Colorado State University, a field study of coyotes on the Rocky Mountain Arsenal (RMA) began in May 1990. Remediation efforts on the RMA might impact significant areas of habitat. These clean-up operations might include mitigation efforts for specific species. Therefore, we investigated home range sizes of coyotes on the RMA to evaluate potential impacts.

STUDY AREA AND METHODS

The Rocky Mountain Arsenal (RMA) comprises 70 km^2 at the northern boundary of Stapleton International Airport in Commerce City, Colorado.

Average elevation is 1600 m with maximum topographical relief of approximately 60 m.

A variety of grasses and forbs are found on the RMA including cheatgrass (Bromus tectorum), crested wheatgrass (Agropyron cristatum), blue grama (Bouteloua gracilis), perennial summercypress (Kochia americana), sand sagebrush (Artemisia filifolia), and rubber rabbitbrush (Chrysothamnus nauseosus). Trees, such as plains cottonwood (Populus sargentii), New Mexican locust (Robinia neomexicana), peach-leaved willow (Salix amygdaloides), and Russian-olive (Elaeagnus angustifolia) are found in localized, dense stands.

A large variety of birds including lark buntings (Calamospiza melanocorys) and western kingbirds (Tyrannus verticalis) are abundant during summer, whereas ferruginous hawks (Buteo regalis) and bald eagles (Haliaeetus leucocephalus) are abundant during winter on RMA. White-tailed deer (Odocoileus virginianus), mule deer (Odocoileus hemionus), black-tailed prairie dogs (Cynomys ludovicianus), black-tailed jackrabbits (Lepus californicus), coyotes, and badgers (Taxidea taxus) are common on the area.

Climate is characterized by low humidity, abundant sunshine, and temperatures averaging -1° C in January and 23° C in July (Natl. Oceanic and Atmos. Adm. 1990). Precipitation averages 37 cm annually with the majority falling between April and July.

Snares (Nellis 1968) and Woodstream Softcatch® traps (Linhart et al. 1986) with attached tranquilizer tabs (Balser 1965, Linhart et al. 1981) were used to capture coyotes. Most traps were set as dirt hole sets (Henderson 1985). Carman's Distant Canine Call, Carman's Final Touch (Russ Carman, New Milford, Pa.), Fatty Acid Scent (Pocatello Supply Depot, Pocatello, Id.), Hawbaker's 600 (S. Stanley Hawbaker & Sons, Fort London, Pa.), W-U lure with 10% Trimethylammonium Decanoate (J-T Eaton & Co. Inc., Twinsburg, Oh.), and coyote urine (Sage Creek Fur Farm, Gilford, Mont.) were used as scents to attract animals to the trap. To help exclude small non-target animals, tension of the trap pan was adjusted to approximately 2.0 kg (Linhart et al. 1981) using a trap pan-tension scale ("H.T.'s Trap-pecker®", Rocky Mountain Wildlife Products, Laporte, Colo.).

Coyotes were fitted with Nasco standard Roto-tags® (Nasco, Fort Atkinson, Wis.) and 167 mHz radiotelemetry collars (Advanced Telemetry Systems Inc., Isanti, Minn.) weighing 235 g. A lower premolar was extracted for cementum annuli age analysis. Radiotelemetry signals were monitored with a model 2000 programmable scanning receiver (Advanced Telemetry Systems, Inc., Isanti, Minn.) attached to a vehicle-mounted dual 4-element null-peak yagi antenna system. Coyotes were located using 2 compass ("KB-20", Suunto, Espoo, Finland) bearings from 2 of 181 receiving stations. Bearings were taken sequentially and averaged 3.2 minutes (SE = 0.02) apart. Accuracy of the compass was verified daily by sighting down 2 straight-lined structures and comparing with reference bearings. Antenna deviation was checked weekly by sighting down 1 of the antenna arrays and on a visible transmitter, and subsequently comparing the antenna deviation from the actual sighting. The telemetry system had an average confidence ellipse of 1578.65 m^2 (SD = 876.99) at 0.8 km using Lenth's (1981) maximum likelihood estimator and an average bearing error (White and Garrott 1990) of -0.91° (SD = 1.15°).

Without simultaneous bearings, we could not evaluate location errors from coyote movements between bearings (Schmutz and White 1990) or determine reflected radio signals (White and Garrott 1990). However, we tried to minimize the time between bearings and generally all transmitter locations were within line of sight of the receiving antenna, which should have minimized reflected signals (White and Garrott 1990).

We used a 95% harmonic mean in program McPAAL (Stuwe and Blohowiak 1985) to generate home range estimates. Coyotes were classified as resident or transient animals based on areal use (Andelt 1985), with individuals using < 13 km^2 classified as resident and those using > 13 km^2 classed as transients.

RESULTS

Ten juvenile and 7 adult coyotes were captured and fitted with radiotelemetry collars in 3,920 trap and 100 snare nights. Adult coyotes averaged 3.3 years old. Eight non-target animals also were captured in traps. We obtained 1,510 locations on 13 coyotes ($\bar{X}$ = 116/coyote) from

November 1990 through March 1991. Home range estimates averaged 6.9 km^2 (SE = 1.0) for resident and 22.5 km^2 (SE = 5.4) for transient coyotes (Table 1).

Discussion

The average coyote home range on the RMA compares favorably with home range estimates from Utah (Hibler 1977), Wyoming (Bekoff and Wells 1980), Alberta (Bowen 1982), and Colorado (Gese et al. 1988).

The effect of remediation on coyotes would depend on the amount of habitat affected on the RMA. Coyotes may be affected by habitat loss and human disturbance such as military maneuvers (Gese et al. 1989). However, the number of coyotes that exist in a group that occupies a home range (Bekoff and Wells 1980, Andelt 1985) should also be considered in determining the effect of remediation on coyotes.

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Table 1. Coyote home range estimates (km^2) on the Rocky Mountain Arsenal from November 1990 through March 1991.

Coyote	Sex	Age	Date Captured	Weight (Kg)	Home range estimate	Number of locations
167.050	F	2[a]	Jul 90	12.7	5.6	164
167.069	F	0[a]	Dec 90	11.8	1.9	83
167.086	M	9[a]	Jul 90	13.2	16.1	205
167.112	F	0[b]	Oct 90	8.6	6.9	89
167.130	F	1[a]	Oct 90	12.5	--[c]	--
167.150	F	0[b]	Oct 90	8.2	--[c]	--
167.171	F	0[a]	Nov 90	9.8	19.8	143
167.191	F	0[b]	Nov 90	8.6	13.1	99
167.212	F	0[a]	Nov 90	9.5	43.4	134
167.230	M	4[a]	Jul 90	13.4	9.0	159
167.251	M	0[b]	Nov 90	12.5	4.6	167
167.270	M	2[a]	Oct 90	15.2	9.8	42
167.310	M	1[a]	Jan 91	14.1	--[c]	6

[a]Age determined from cementum annuli.

[b]Age determined from coyote size and tooth eruption.

[c]Could not be located shortly after being radio collared.

Table 1. Continued.

Coyote	Sex	Age	Date Captured	Weight (Kg)	Home range estimate	Number of locations
167.442	F	0[b]	Jan 91	9.5	10.2	71
167.480	F	0[a]	Dec 90	11.8	--[c]	--
167.691	F	4[a]	Jan 91	13.6	7.4	49
167.880	F	0[b]	Jul 90	4.3	20.0	105

[a]Age determined from cementum annuli.

[b]Age determined from coyote size and tooth eruption.

[c]Could not be located shortly after being radio collared.

DOCUMENTATION AND INTERPRETATION OF SELECTED WILDLIFE HABITAT RELATIONSHIPS AT THE ROCKY MOUNTAIN ARSENAL

Task One: Small Rodents

By

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and

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1992 Annual Progress Report

31 December, 1992

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Abstract: Two experimental procedures were initiated for the small rodent task in 1992: 1) a soil disturbance and remediation protocol mimicking projected cleanup activities, and 2) small scale habitat alterations designed to test population responses to less severe disturbances. Preliminary results indicated that deep soil disturbance (plowing) eliminates small mammal use of the affected areas in the short term. No response to small scale habitat disturbances was observed, suggesting that rodent habitat use is primarily influenced by large scale habitat features, such as habitat type and gross physiognomy. Rodent densities on the Rocky Mountain Arsenal in 1992 were consistently lower than in 1991, especially during the fall.

During 1992, the small rodent study on the Rocky Mountain Arsenal moved into its experimental phase, with two major goals; to directly test the response of rodent populations to severe soil disturbance and subsequent vegetative restoration, and to determine the scale of habitat alteration to which rodents are most sensitive. Both efforts were successfully initiated and should ultimately provide information useful for making decisions on a final cleanup protocol.

Additionally, all data from 1991 have been analyzed and will shortly be submitted for publication. Results of this analysis were included in the Quarterly Progress Report for the second quarter of 1992.

METHODS

Sampling Protocol

Live trapping techniques and vegetative measurements were identical to those used in 1991. All grids were trapped in June and in October. Vegetation was sampled in late June and early July.

Plowing and Restoration Experiments

Two weedy forb grids and two crested wheatgrass grids were selected to undergo a standardized remediation and restoration protocol that approximates disturbances associated with cleanup activities. The treatment grids were paired with untreated grids of the same habitat type to serve as controls. Additional grids were established about 60 m from the treated grids to census rodent species that could potentially use the disturbed areas. No native habitat grids were subjected to this treatment because intense cleanup and restoration activities are less likely to occur in these habitat types. Treated grids were mowed in May to reduce seed production by weedy plants. The two weedy forb grids were mowed again in June and treated with Roundup herbicide. Grids were moldbored (plowed) in late June and July, and were seeded and mulched in October. These procedures were performed by Morrison-Knudsen Co., an Arsenal contractor. During the June trapping session, the treated grids were covered by mowed vegetation, and during October were entirely covered by bare, plowed soil.

Habitat Alterations

On ten native habitat grids, vegetation was altered in parallel strips (2.5 m width, separated by ~28 m) that covered half of the trapping stations, but affected less than 10% of the entire grid. Two types of treatment were performed:

1) Reduction of cover by mowing vegetation to a 6 cm height with a weed mower, and subsequent removal of all litter by raking. This treatment was performed on two sanddropseed grids, two sandsagebrush grids, and one shortgrass grid dominated by needle-and-thread grass (*Stipa comata*). All of these habitat types were considered 'high-cover' sites based on previous analyses. Bare-ground was substantially increased, and vertical vegetation density substantially reduced in the treated strips. Each treated grid was paired with an untreated grid of the same habitat type to act as a control.

2) Enhancement of cover by addition of a layer of straw. Bare ground was eliminated and 'litter' increased on the parallel strips. This treatment was performed on five 'low-cover' sites, including two prairie dog grids, two yucca grassland grids, and one shortgrass grid dominated by blue grama grass (*Bouteloua gracilis*). Paired control grids were selected as above.

Both treatments were performed about two weeks prior to June trapping, and repeated two weeks prior to October trapping.

Analysis

Analysis of 1992 results is currently in progress. Therefore the conclusions discussed below are preliminary.

RESULTS

Live Trapping

During the summer field season, 2400 trap nights produced 616 captures of 334 individual small mammals (Table 1). Trap success was 26%. Eight species were tallied: the deer mouse (Peromyscus maniculatus), thirteen-lined ground squirrel (Spermophilus tridecumlineatus), Western harvest mouse (Reithrodontomys megalotis), prairie vole (Microtus ochrogaster), Ord's kangaroo rat (Dipodomys ordii), spotted ground squirrel (Spermophilus spilosa), plains pocket mouse (Perognathus flavescens), and hispid pocket mouse (P. hispidus).

The fall field season produced 173 captures of 106 individual animals over 2100 trap nights (300 trap nights were cancelled due to weather). Trap success was 8.2% (Table 2). The Northern grasshopper mouse (Onychomys leucogaster) was present, and the spotted ground squirrel absent from the fall sample. Other species were present during both seasons.

Species' affinities for certain habitat types was consistent with 1991 results. Deer mice and thirteen-lined ground squirrels tended to be most numerous in low cover habitats (yucca grassland, prairie dog towns, weedy forbs, some shortgrass) with much bare ground. Western harvest mice and prairie voles were most numerous in habitats with high vegetative cover and dense litter (sandsagebrush, sanddropseed grassland, some shortgrass grids).

Restoration and Remediation Grids

No formal statistical analysis has been performed on these data at present. Trends for minimum number of animals alive on restoration grids are given in Figures 1 and 2. No animals were captured on any treated grid in October following plowing, although small rodents were present in adjacent habitat.

Habitat Alterations

These data have not been statistically analyzed. However, a preliminary examination of results suggests that neither type of habitat alteration markedly affected small rodent numbers at the whole grid level, or altered capture ratios between treated and untreated trapping stations.

DISCUSSION

Population Densities

Rodent population densities appeared to be substantially lower in 1992 than 1991, after the possible influence of habitat alteration and remediation treatments was accounted for. Minimum number of animals alive for summer 1991 was 487; for summer 1992, 334; for fall 1991, 265; for fall 1992, 106. Reduction in fall densities relative to summer densities (partly due to hibernation of thirteen-lined ground squirrels) was more pronounced in 1992 than in 1991. The plains pocket mouse was the only species consistently more common in 1992 than 1991. No factor responsible for low rodent densities in 1992 has yet been identified.

Restoration and Remediation Grids

Plowing of remediation grids appeared to preclude use of the area by rodents, either through direct mortality or by habitat degradation. Although the duration of this effect is not known, it suggests that cleanup related activities may have important short-term impacts on prey availability, especially if conducted on an extensive scale.

Habitat Alterations

Principle component analyses conducted on 1991 data implied that rodent distributions at the Arsenal are influenced by large-scale habitat features (such a habitat type or gross physiognomy). Most studies of small mammal communities have, in contrast, stressed the importance of microhabitat variation (variation within an animal's home range) to habitat selection. The habitat alteration experiments performed in 1992 were intended to test the possible effects of microhabitat variation on rodent habitat use. Preliminary examination of these data suggest that microhabitat variation is a relatively unimportant factor in determining rodent distributions at the Arsenal.

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FURTHER WORK

1) Publication of 1991 results

2) Complete analysis of 1992 data: time series comparisons of remediation treatment grids, comparison of habitat alteration treatment grids with control grids, comparison of capture rates of treated trap stations with untreated trap stations.

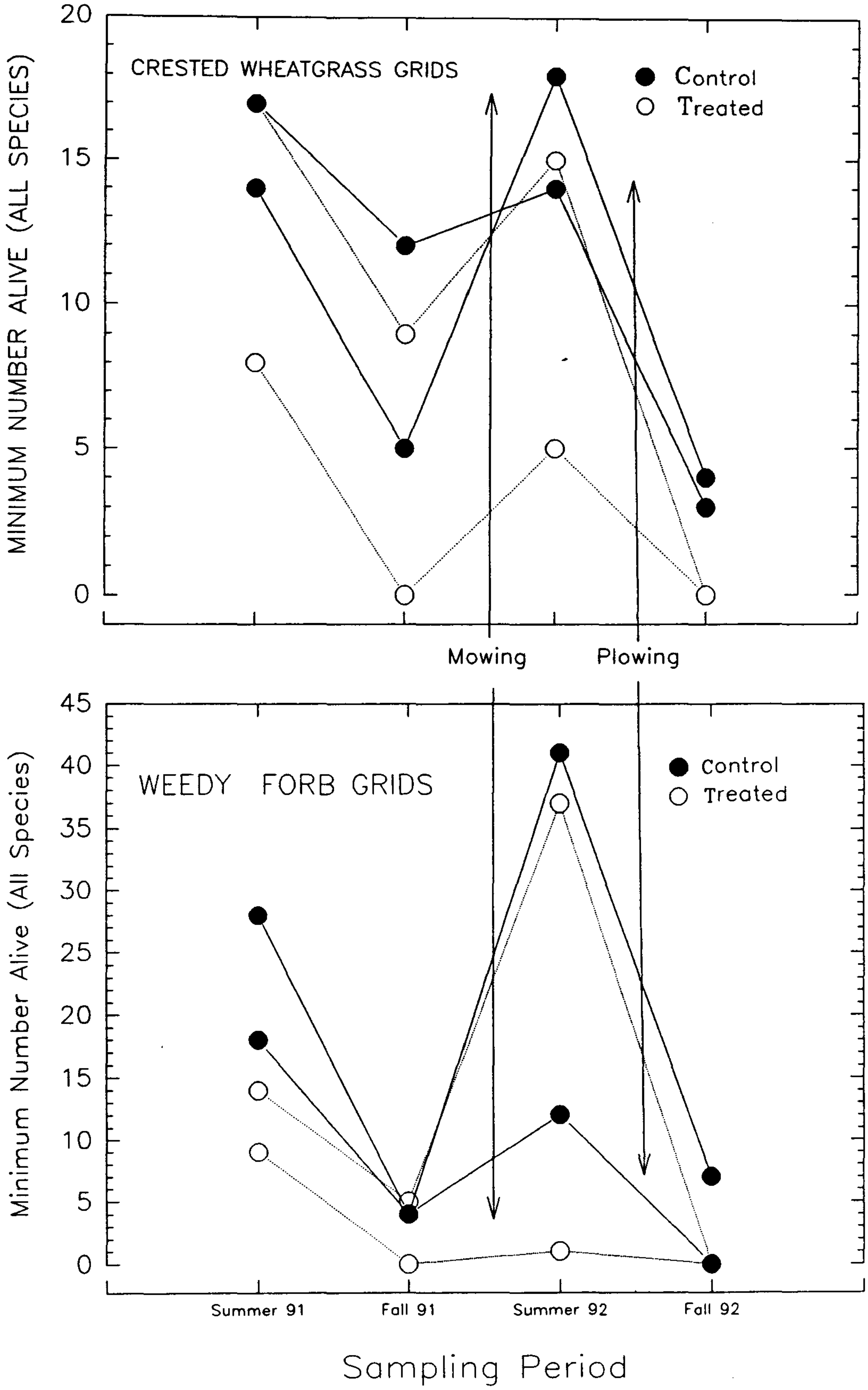
3) Design extension of habitat alteration experiments to the whole grid level.

Table 1. Minimum number of small rodents alive on trapping grids for seven habitat types on the Rocky Mountain Arsenal, summer 1992. Each value is the sum for four grids. Habitat type codes are: SS=sandsage, YG=yucca grassland, SD=sanddropseed grassland, SG=shortgrass, PD=prairie dog town, WF=weedy forb, CW=crested wheatgrass.

SPECIES	SS	YG	SD	SG	PD	WF	CW	TOTAL
Deer mouse	15	18	1	7	13	64	20	138
13-lined gr. sq.	1	12	2	29	8	10	17	79
W. harvest mouse	22	5	7	5	0	0	4	43
Prairie vole	14	11	7	2	1	0	0	35
Ord's k. rat	5	0	1	2	1	0	2	11
Plains pocket m.	8	1	6	2	4	2	0	22
Hispid pocket m.	0	0	2	0	2	0	0	4
Spotted gr. squir.	0	0	0	2	0	0	0	2
TOTAL	65	47	26	49	29	76	43	334

Table 2. Minimum number of small rodents alive on trapping grids, fall 1992.

SPECIES	SS	YG	SD	SG	PD	WF	CW	TOTAL
Deer mouse	5	13	0	0	2	22	5	47
13-lined gr. sq.	0	1	0	2	0	1	1	5
W. harvest mouse	8	9	6	2	2	0	4	31
Prairie vole	0	0	5	0	0	0	0	5
Ord's k. rat	1	6	0	0	0	0	0	7
Plains pocket m.	4	0	2	0	0	0	0	6
Hispid pocket m.	0	0	0	0	0	0	1	1
N. grasshopper m.	0	0	0	0	2	0	2	4
TOTAL	18	29	13	4	6	23	13	106



FIGURES 1 AND 2. Minimum number of small smmals alive on remediation grids and their controls.

DOCUMENTATION AND INTERPRETATION OF SELECTED WILDLIFE HABITAT RELATIONSHIPS AT THE ROCKY MOUNTAIN ARSENAL

TASK TWO: SMALL BIRDS

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Abstract: Birds were surveyed in the same 28 plots (7 vegetation types x 4 replicates) during summer and fall 1992 as in 1991. Additionally, small scale habitat alteration of disturbed grassland plots was employed in 1992 to determine short-term effects on birds. A total of 35 species was recorded across all plots during the breeding season, and 21 species were recorded during fall surveys (two-season total of 50 species). The total number of birds recorded in 1992 was lower than in 1991. Numbers of species and individuals were generally lower in mowed plots compared with controls, although a few species may have experienced a short-term benefit from mowing.

The experimental phase of the small bird study was begun in 1992. Results from this year document short-term response of birds to mowing, and results from future years will help determine long-term effects of grassland alteration and restoration.

METHODS

Sampling protocol

Avian survey techniques and vegetative measurements were identical to those used in 1991. All plots were surveyed in June and again in late October - early December 1992.

Plowing and restoration experiments

Two weedy forb plots and two crested wheatgrass plots were selected to undergo a standardized remediation and restoration protocol that approximates disturbances associated with cleanup activities. The treatment plots were paired with untreated plots of the same vegetation type to serve as controls. No native habitat plots were subjected to treatment because intense cleanup and restoration activities are less likely to occur in these habitats. Treated plots were mowed in May to reduce seed production by weedy plants. The two weedy forb plots were mowed again in June and July and treated with Roundup herbicide. Plots were plowed and seeded with a native grass seed mixture in late August and September, and were mulched in late October. These procedures were performed by Morrison-Knudsen Engineers, Inc.

Analysis

Summary results are presented below. Specific analyses are ongoing, and conclusions prior to completion of the study would be premature.

RESULTS

General Summer

Thirty-five species were recorded across all vegetation types in June 1992 (Table 1). Species richness and total abundance were higher in sand sagebrush than in any other vegetation type. Species richness and abundance were generally lowest in crested wheatgrass, prairie dog, and other shortgrass plots. The total number of birds observed in 1992 was 22% lower than in 1991.

General Fall

Twenty-one species were recorded across all vegetation types during fall surveys (Table 2). Species richness and total abundance were highest in sand dropseed and prairie dog plots.

Comparison of Treatment with Control Plots in Summer

As expected, species richness and individual abundance were much lower in mowed crested wheatgrass and weedy forb plots than in controls (Table 3). Interestingly, Killdeer were only observed on mowed plots of these vegetation types. Similarly, Western Kingbird was observed on mowed crested wheatgrass plots, but not on control wheatgrass plots.

DISCUSSION

For the purposes of this annual progress report, all birds observed in a study plot are included, regardless of use status. The final report will focus on species that depend on study plots for nesting, shelter, and or food. Results from 1992 underscore the value of Arsenal habitats, particularly native scrub/shrub vegetation, in supporting a diverse assemblage of breeding birds. The reduced number of individuals recorded in 1992 probably represents normal yearly fluctuations rather than any trend. Of the eight species recorded in 1991 that were not found in 1992, the Eastern Meadowlark merits comment. One observer reported this species on 14 plots in 1991, but no one else was able to corraborate the identification. Despite the concerted efforts of both authors in 1992, we were unable to identify a single Eastern Meadowlark. Therefore, we attribute identification of Eastern Meadolarks in 1991 to observer error. Eastern and Western Meadowlarks can be very difficult to distinguish from calls, and future efforts should be made to capture and examine meadowlarks in hand.

GOALS THROUGH 1993

1) Complete detailed analysis of 3 breeding season richness and abundance patterns.
2) Complete detailed analysis of 3 nonbreeding season richness and abundance patterns.
3) Measure and compare reproductive parameters in selected control and treatment plots.
4) Complete detailed analysis of 2-year effects of remediation/restoration experiment.

TABLE 1. Number of birds/plot/survey observed in crested wheatgrass (CW), prairie dog (PD), sand dropseed (SD), shortgrass (SG), sand sagebrush (SS), weedy forb (WF), and yucca (YG) vegetation types during June 1992.

Species	CW	PD	SD	SG	SS	WF	YG
Double-crested cormorant	-	-	-	-	.08	-	-
Great Blue Heron	-	-	-	-	.08	-	-
Mallard	-	-	-	-	.33	.17	.17
Swainson's Hawk	-	-	.08	.17	-	-	-
Red-tailed Hawk	-	-	-	-	-	-	.08
American Kestrel	-	-	.17	.08	-	-	.25
Ring-necked Pheasant	.08	-	-	-	.08	.17	-
Killdeer	-	.25	-	-	.17	-	-
Ring-billed Gull	.08	-	-	-	-	-	-
Mourning Dove	.42	.75	.42	1.5	.75	.75	.75
Burrowing Owl	-	.50	-	-	-	-	.50
Western Kingbird	-	-	.83	.33	.67	.50	.75
Eastern Kingbird	.17	-	.33	-	-	-	-
Horned Lark	1.0	4.1	-	.08	-	-	-
Barn Swallow	-	-	-	-	.17	-	-
Black-billed Magpie	.08	1.0	1.9	.17	1.0	.08	-
House Wren	-	-	.33	-	-	-	-
American Robin	-	-	-	-	.08	.33	-
Loggerhead Shrike	-	-	.08	-	-	-	-
European Starling	-	2.0	.17	-	-	-	-
Common Yellowthroat	-	-	.08	-	-	-	-
Cassin's Sparrow	-	-	-	.33	.75	-	.75
Vesper Sparrow	-	-	-	-	-	-	.25
Lark Sparrow	-	-	-	-	-	.08	-
Lark Bunting	3.9	2.2	.17	1.2	2.7	6.2	.17
Savannah Sparrow	-	-	-	-	.25	-	-
Grasshopper Sparrow	.83	.08	1.5	1.4	.67	.17	.33
Red-winged Blackbird	-	-	-	-	.17	.42	.17
Western Meadowlark	2.7	2.7	5.0	4.6	7.7	3.2	7.2
Brewer's Blackbird	.08	-	-	.50	.58	1.2	.17
Common Grackle	.08	-	.08	-	-	.33	-
Northern Oriole	.08	-	.58	-	.25	.67	.58
House Finch	-	-	1.5	2.7	-	-	-
American Goldfinch	-	-	-	-	.17	-	.08
House Sparrow	-	.17	-	-	.08	-	-
Total species	**12**	**11**	**16**	**11**	**20**	**14**	**16**
Birds/plot/survey	**9.5**	**13.7**	**12.4**	**13.1**	**16.7**	**14.3**	**12.2**

TABLE 2. Number of birds/plot/survey observed in crested wheatgrass (CW), prairie dog (PD), sand dropseed (SD), shortgrass (SG), sand sagebrush (SS), weedy forb (WF), and yucca (YG) vegetation types during fall 1992 surveys.

Species	CW	PD	SD	SG	SS	WF	YG
Canada Goose	-	-	6.3	-	-	-	-
Bald Eagle	-	-	.08	-	-	.08	-
Red-tailed Hawk	-	-	.08	-	-	-	-
Ferruginous Hawk	-	.43	.08	-	.17	-	-
Rough-legged Hawk	-	.08	.17	-	-	-	-
American Kestrel	-	.08	.08	-	-	-	-
Prairie Falcon	-	.08	.08	-	-	-	-
Chukar	-	-	-	-	.58	-	-
Great Horned Owl	-	-	.08	-	-	-	-
Downy Woodpecker	-	-	.08	-	-	-	-
Northern Flicker	-	.17	-	.08	.08	-	.08
Horned Lark	4.0	10.9	.33	1.0	1.4	2.4	.33
Black-billed Magpie	-	.58	.83	-	1.2	-	.75
Black-capped Chickadee	-	-	.25	-	-	-	-
European Starling	-	2.1	.42	-	.67	-	-
American Tree Sparrow	-	.17	2.0	-	-	-	.50
White-crowned Sparrow	-	-	.08	-	-	-	-
Lapland Longspur	-	-	-	2.6	.17	-	.42
Dark-eyed Junco	-	-	.67	-	-	-	-
Western Meadowlark	.17	.25	.42	.25	.33	.50	.17
House Finch	.17	1.1	.17	.08	-	-	-
Total species	**3**	**11**	**18**	**5**	**8**	**3**	**6**
Birds/plot/survey	**4.3**	**15.9**	**12.2**	**4.0**	**4.6**	**3.0**	**2.2**

TABLE 3. Comparison of avian species richness and number of birds/plot/survey observed in mowed and unmowed crested wheatgrass (CW) and weedy forb (WF) plots in June 1992.

Species	CW	mowed CW	WF	mowed WF
Mallard	-	-	.17	-
Ring-necked Pheasant	.08	-	.17	-
Killdeer	-	.25	-	.08
Ring-billed Gull	.08	-	-	-
Mourning Dove	.42	.67	.75	-
Western Kingbird	-	.83	.50	.25
Eastern Kingbird	.17	.08	-	-
Horned Lark	1.0	.58	-	-
Black-billed Magpie	.08	.08	.08	-
American Robin	-	-	.33	-
Lark Sparrow	-	-	.08	-
Lark bunting	3.9	1.5	6.2	1.5
Grasshopper Sparrow	.83	.08	.17	-
Red-winged Blackbird	-	-	.42	-
Western Meadowlark	2.7	1.0	3.2	.75
Brewer's Blackbird	.08	-	1.2	-
Common Grackle	.08	-	.33	-
Northern Oriole	.08	-	.67	.08
Total species	**12**	**9**	**14**	**5**
Birds/plot/survey	**9.5**	**5.1**	**14.3**	**2.7**

DOCUMENTATION AND INTERPRETATION OF SELECTED WILDLIFE HABITAT RELATIONSHIPS AT ROCKY MOUNTAIN ARSENAL

Task Three: Lagomorphs

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The results presented in this report are preliminary and may not be cited or otherwise published without the written consent of the authors.

Bennett, Preston

Abstract: Line-transect counts were conducted in 1991-92 to estimate densities of black-tailed jackrabbits (Lepus californicus) and cottontails (Sylvilagus spp.) on the Rocky Mountain Arsenal. Estimated lagomorph densities were slightly lower in 1992 than in 1991. Neither jackrabbits nor cottontails were distributed evenly across the sampling areas. Numbers of L. californicus sharply declined in August of both years, possibly due to migration to mowed areas adjacent to the Arsenal.

INTRODUCTION

Black-tailed jackrabbits (Lepus californicus) and cottontail rabbits (possibly two species, Sylvilagus audubonii and S. floridanus) are common on the Rocky Mountain Arsenal. These lagomorphs have been deemed important prey items for raptors and other predators on the Arsenal, particularly after 1988 when prairie dogs (Cynomys ludovicianus) were decimated by sylvatic plague (Meaney et al. 1991). Habitat alterations that affect the distribution and abundance of lagomorphs probably will impact populations of raptors and other species of special interest on the Arsenal.

Meaney et al. (1991) determined that the nocturnal spotlight count was the most efficient census technique to estimate lagomorph numbers on the Arsenal. Consequently, spotlight counts were used to accomplish the objective of this study, which was to determine geographic distribution and densities of lagomorphs on the Arsenal in 1991 and 1992.

METHODS

Spotlight counts were done in a manner similar to that described by Smith and Nydegger (1985). A pickup truck was driven 10 km/hr while two spotters stood in the back, each with a spotlight (Brinkmann Q-Beam 100,00/200,00 candlepower). When a lagomorph was spotted, its identification (Lepus or Sylvilagus), its location, and its perpendicular distance from the road were recorded.

Two sets of transects, on back roads and main roads, were used for spotlighting. Back-road transects (Fig. 1) were non-section dirt roads that were surveyed in both 1991 and 1992. In August 1992 roads 4, 11, 12, 13, 22, and 24 were eliminated from further spotlighting. Each back-road transect was spotlighted twice in June, August, and October of 1992. Main-road transects (Fig. 2) were driven along section roads and were identical to raptor survey transects used in Task Four. These transects were not surveyed in 1991 and were surveyed twice in July and September 1992.

Absolute lagomorph densities were estimated with the DISTANCE computer program (Burnham et al. 1980). This program analyzes the perpendicular distances to compute an "Effective Strip Width", which is a measure of the average sighting distance along the transect. The program then determines densities by including information on transect length and number of sightings. Some assumptions of the program are that objects do not move before they are seen, objects on the road are always seen, and the road does not affect distribution of the objects (Burnham et al. 1980).

RESULTS

The total number of lagomorphs seen per km of road was smaller in 1992 than in 1991 (Fig. 3A). Fewer jackrabbits and cottontails were seen in 1992, with the exception of a large number of jackrabbits in October. The DISTANCE program also computed smaller densities of lagomorphs in 1992 (Fig. 3B), but the differences were not as extreme because the effective strip width was narrower in 1992 than in 1991 (Fig. 3C).

The densities of lagomorphs on the main-road transects were similar to densities found on the back-road transects (Figs. 3A, 3B). The effective strip width (Fig. 3C) was slightly narrower on the main roads than on the back roads for both jackrabbits and cottontails.

In both August 1991 and August 1992 the estimated density of jackrabbits decreased sharply before returning to June levels in September 1991 and October 1992 (Fig 3B). However, cottontail densities increased in August 1991 and 1992.

In most cases effective strip widths were larger for jackrabbits than for cottontails (Fig. 3C). This is likely due to jackrabbits' slightly larger size and to their habit of fleeing, which allows them to be seen at distances greater than cottontails. Most of the effective strip widths in 1992 were narrower than in 1991.

Lagomorphs were not evenly distributed across the Arsenal. This patchiness was especially noticeable in 1992, when jackrabbits were almost completely restricted to the three sections (9, 3, 11) bordering Stapleton Airport (Table 1). Cottontails were more widely distributed across the Arsenal, but still were patchy in occurrence (Table 2). Back-road transects 17 - 20, located in the north-eastern sections of the Arsenal, had a large reduction in lagomorph sightings from 1991 to 1992. The largest concentrations of lagomorphs on the Arsenal occurred on back roads 1 and 2, which are located on the isolated piece of land on the western portion of section 9 (Tables 1 and 2). The main-road transects (Table 3) showed patches of high lagomorph densities near the airport and near the South Plants in sections 1 and 2.

DISCUSSION

The DISTANCE program proved useful for comparison of lagomorph densities at different sampling dates, because sightings of lagomorphs are dependent on the height of the vegetation and the behavior of the animals, neither of which remains constant. The densities computed by DISTANCE should not be considered absolute, because they are associated with large standard errors and the assumptions of the program were not entirely met.

The decrease in lagomorph sightings from 1991 to 1992 might be due to an Arsenal-wide decrease in populations, to changes in vegetation structure, or to some other factor. The DISTANCE program computed narrower strip widths in 1992, but the estimated densities also were slightly lower. Decreases in both sightings and strip widths were possibly due to an increase in vegetation height from 1991 to 1992. Although vegetation height was not measured in 1992, both the spring and summer were wet and mild.

Rabbit surveyors created less habitat disturbance on the main-road transects than on the back roads. Counts on the main roads were more likely to violate assumptions of the DISTANCE program, especially regarding effects of roads on lagomorph distribution, but estimated densities were similar on main and back roads. The narrower strip widths on the main roads were likely due to the increased visibility of lagomorphs near roads.

Reasons for the concentration of lagomorphs in the south-western region of the Arsenal are unclear. Preliminary analyses of habitat preferences show no significant associations with any habitat, other than an avoidance of riparian areas. It has been suggested that lagomorphs use mowed areas on the airport on a diurnal or seasonal basis, but this hypothesis has not been tested.

The decrease in jackrabbit densities in August of 1991 and 1992 might be attributed to migration. Lagomorphs have been found to migrate seasonally to exploit crop resources (Scribner and Warren 1990). Off-site resources might be instrumental in maintaining jackrabbit populations on the Arsenal. Radio tracking in 1993 should determine whether seasonal migration is occurring.

Bennett, Preston

PLANS FOR 1993

1. Trap lagomorphs and attach radio transmitters.

2. Conduct weekly and diurnal radio monitoring.

3. Conduct spotlight transects.

4. Evaluate responses of lagomorphs relocated to areas of prairie restoration and other manipulated areas.

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Figure 1. Offroad lagomorph spotlight transects.

LAGOMORPH SPOTLIGHT TRANSECTS

ROCKY MOUNTAIN ARSENAL

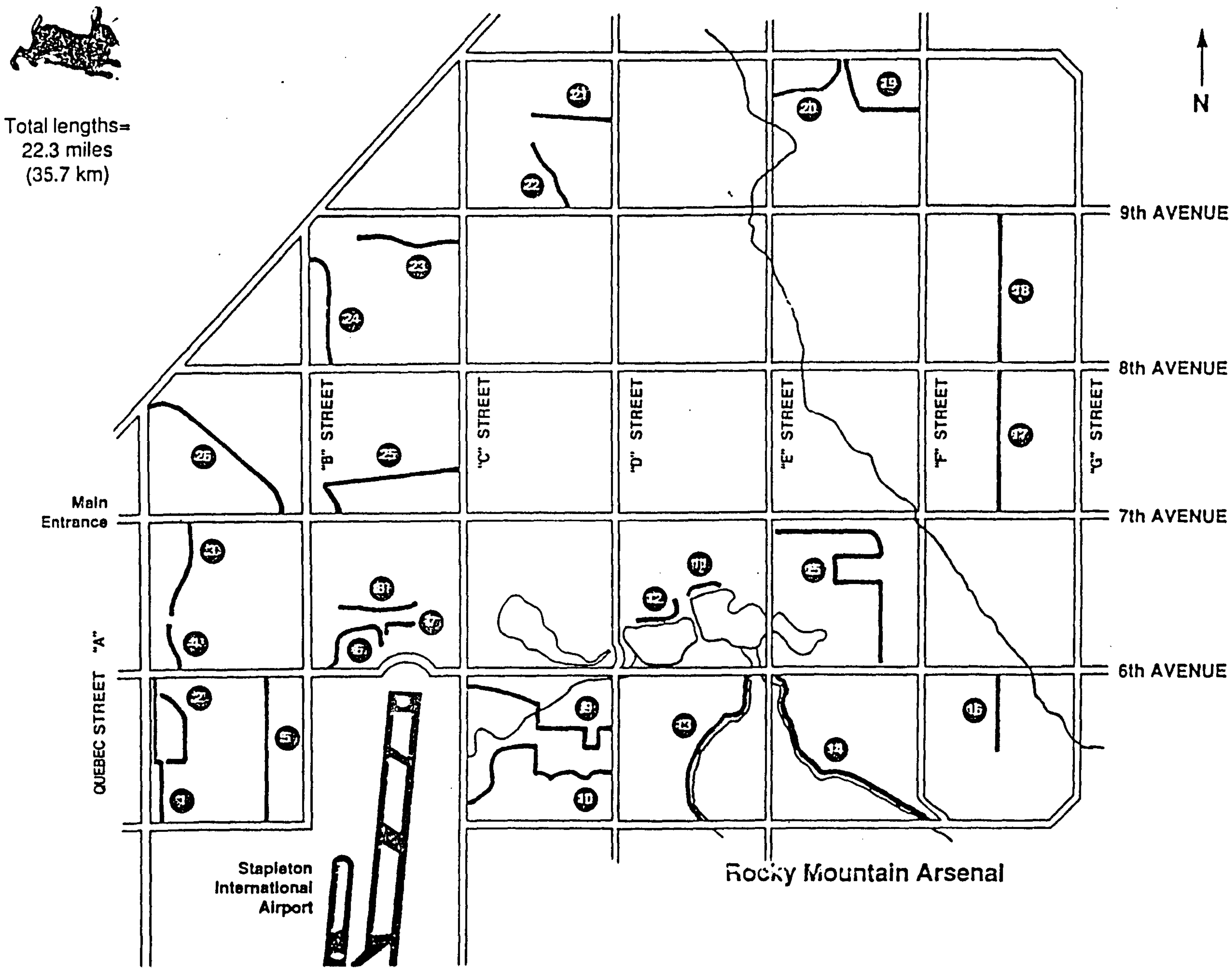

Figure 2. Main road lagomorph spotlight transects.

Figure 3. Spotlight transect data from June 1991 to October 1992. All dates are for offroad transects except July and September 1992. Fig. 3A shows number of lagomorphs/km road driven. Fig. 3B represents number of lagomorphs/ha from DISTANCE with half normal key. Fig. 3C is Effective Strip Width using half normal key.

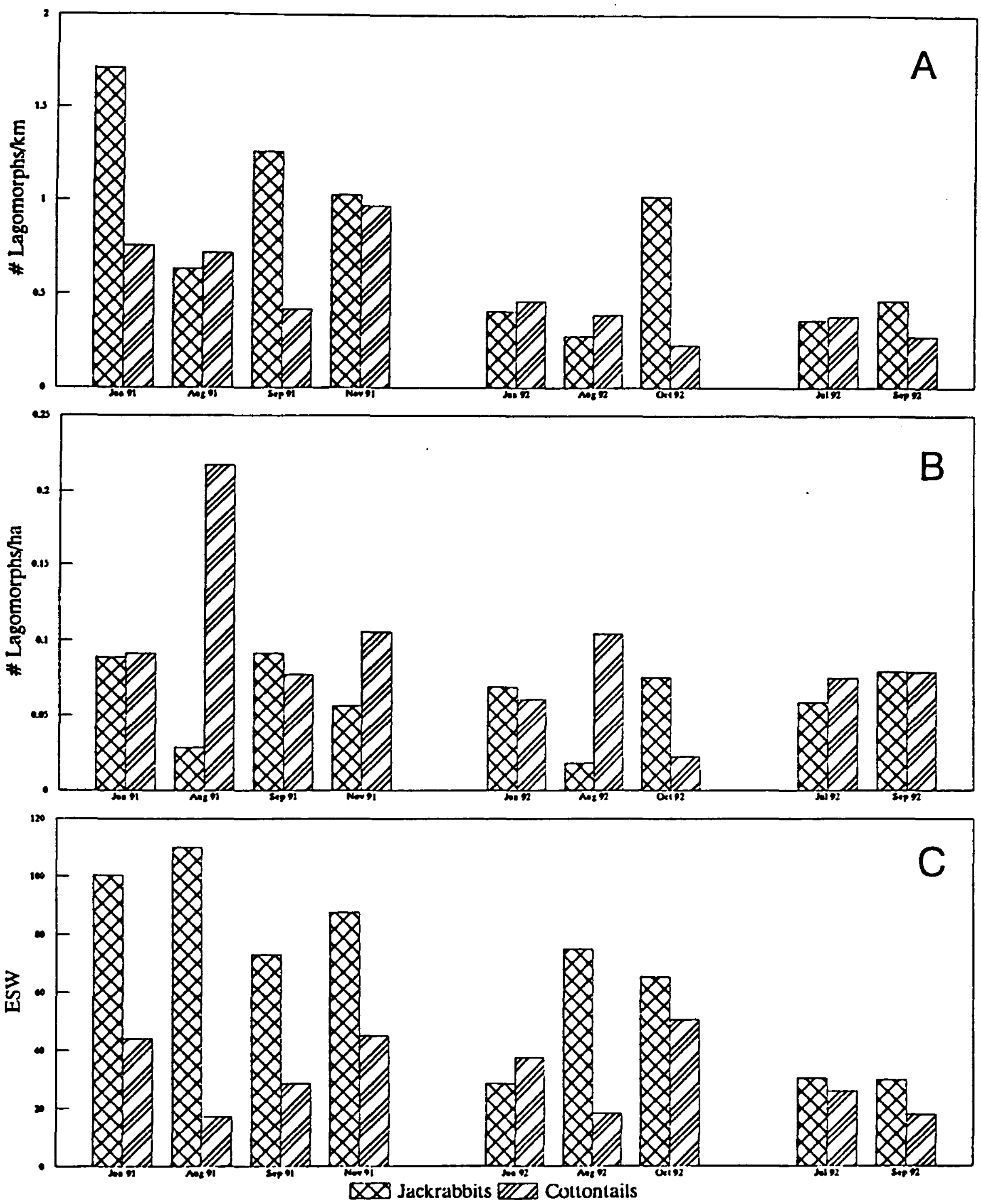
A
Lagomorphs/km
2
1.5
1
0.5
0
Jun 91
Aug 91
Sep 91
Nov 91
Jun 92
Aug 92
Oct 92
Jul 92
Sep 92
B
Lagomorphs/ha
0.25
0.2
0.15
0.1
0.05
0
C
ESW
120
100
80
60
40
20
0
Jackrabbits
Cottontails

Table 1. Number of Jackrabbits per kilometer of back roads broken down by road and month. Shaded areas were not studied.

	Jackrabbits						
Road #	Jun91	Aug91	Sep91	Nov91	Jun92	Aug92	Oct92
1	5.58	8.68	9.92	9.92	0.93	1.86	11.16
2	10.90	0.68	2.73	0.68	0.68	0.68	5.11
3	0	0	0	0	1.55	0	0.78
4	12.40	0	0	0	0		
5	4.34	0	1.24	1.24	0.31	0	0.93
6	4.77	0.95	4.77	0	3.82	0.48	1.91
7	3.10		9.30	3.10	6.20	1.55	0
8	3.72		2.48	1.24	0.62	2.48	1.24
9	1.68	0.42	2.09	0	0.21	0.21	0
10	1.35	0	0	1.35	0.90	0	0
11	0	0	0	0	0		
12	0	1.27	0	1.27	0		
13	1.02	0	0	0	0		
14	0	0	0	0	0	0	0
15	0.22	0	0		0.11	0	0
16	0	0	0	2.86	0	0	0
17	0	0	0	0	0	0	0
18	0	1.24	1.24	1.24	0	0	0
19	0.81	0.81	2.42	2.42	0	0	0
20	0.89	0	0	0	0	0	0
21	0	0	0	0	0	0	0
22	1.24	1.24	1.24	0	0		
23	0	0	0	0	0	0	0
24	0	0	0.95	0	0		
25	1.31	0	0	0	0	0.65	0
26	1.13	0	0.56	0	0	0	0
TOT	1.69	0.62	1.25	1.02	0.40	0.27	0.99

Table 2. Number of cottontails per kilometer of back roads broken down by road and month. Shaded areas were not studied.

	Cottontails						
Road #	Jun91	Aug91	Sep91	Nov91	Jun92	Aug92	Oct92
1	3.10	2.48	1.86	3.10	1.55	2.17	1.55
2	1.36	1.36	1.36	2.73	2.04	2.73	2.04
3	0	0	0	0	0	0	0
4	0	4.13	0	0	0		
5	0.62	0.62	0	0.62	0.31	0.31	0
6	0	0	1.91	2.86	1.91	1.91	0
7	0		0	0	0	0	3.10
8	0		0	0	0	0	0
9	0	0.84	0	1.26	0	0	0
10	1.80	0	0	0.90	2.47	0	0
11	0	0	4.43	0	0		
12	0	0	0	0	0		
13	0	0	0	0	0.25		
14	0	0	0	0	0	0	0
15	0.22	1.12	0		0.11	0	0
16	0	0	0.95	0	0	0	0
17	1.86	1.86	0	0.62	0	0	0
18	3.72	0	1.24	1.86	0	0	0.31
19	0.81	0	0.81	1.61	1.21	0	0
20	1.77	1.77	1.77	5.31	0	0	0
21	0	0	0	0	0	0	0
22	0	1.24	0	0	0		
23	2.14	1.07	0	0	0.53	0.53	0
24	0	0	0	0.95	0		
25	0	1.31	0	0.65	0	0	0
26	0	0.56	0	0	0	0	0
TOT	0.75	0.71	0.42	0.99	0.46	0.38	0.22

Table 3. Number of lagomorphs per kilometer of main roads broken down by species, road, and month.

	July		September	
Road	J	C	J	C
1	2.79	2.48	2.48	0.62
2	2.17	0.62	6.51	0
3	0	0	0	0
4	0	0	0	0
5	1.55	0	0.62	0
6	0	0	0	0
7	0	0.62	0.31	0.31
8	0	0	0	0.31
9	0	0	0	0.31
10	0	0.31	0.31	0
11	0	0.62	0	0.31
12	0.31	0	0	0
13	0	0.31	0	0.31
14	0	0	0	0
15	0	0	0	0
16	0	0	0	0
17	0	0	0	0
18	0	0.31	0	0
19	0	0	0	0
20	0	0	0.31	0.31
21	0	0.31	0	0
22	0.62	0.31	0.31	0
23	0.31	1.55	0.31	0.31
24	0.31	0.31	0	0.62
25	0	0	0.62	0
26	0	1.02	0	1.36
27	0	1.00	0	2.26
28	1.11	1.39	1.39	0.83
29	1.24	0	0.31	0
Total	0.36	0.38	0.46	0.27

DOCUMENTATION AND INTERPRETATION OF SELECTED WILDLIFE HABITAT RELATIONSHIPS AT THE ROCKY MOUNTAIN ARSENAL

TASK FOUR: FERRUGINOUS HAWK

by

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Abstract: The abundance, distribution, average home range, and diet of ferruginous hawks (Buteo regalis) overwintering at the Rocky Mountain Arsenal (RMA) is currently being investigated. Included in this investigation is the potential impacts of disturbance to ferruginous hawks caused by cleanup operations and wildlife viewing. Eight ferruginous hawks were captured and radio-tagged during the winter 1991/92. Six of these were monitored a minimum of twice weekly through March 1992. Twelve ferruginous hawks were captured in November and December 1992 and fitted with tail-mounted radio-transmitters to be monitored through March 1993. Radio-tagged hawks were monitored individually using hand-held receivers and visual observations. Habitat use of all falconiformes was investigated during roadside surveys conducted on RMA. Forty-three roadside surveys have been conducted on RMA and will continue through 1993. Castings and prey remains were collected from beneath Swainson's hawk (Buteo swainsoni) nests and ferruginous hawk winter roosts for diet analysis. Ferruginous hawks will be monitored throughout the winter and spring 1993 and again during the winter and spring of 1994 to determine habitat use, distribution, and home range estimates. Simulated human disturbance experiments will be initiated in January 1993 to determine impacts of various RMA related activities. Studies of communal roost characteristics began in November 1992 and will continue through the winter of 1993/94.

INTRODUCTION

In 1991 the Denver Museum of Natural History (DMNH) entered into a cooperative agreement with the U. S. Fish and Wildlife Service (FWS), to conduct a comprehensive ecological study at the Rocky Mountain Arsenal (RMA). Funding for this project was provided by the U.S. Army. This multi-faceted study involves the ecological relationships between habitat and vertebrate communities including, small birds, small mammals, lagomorphs, and raptors. Current interim actions and eventual remediation of hazardous waste associated the RMA could potentially destroy thousands of acres of wildlife habitat. Management decisions and mitigation measures will be implemented based on the best available information. Therefore, it is pertinent to understand wildlife-habitat relationships, including raptor-habitat relationships, prior to remediation.

Diurnal raptors are the most visible predators at RMA. Because of their position at the top of the food chain and their great mobility, they are valuable as environmental barometers. Diurnal raptors are especially integral in the functioning of grassland ecosystems. The Ferruginous Hawk (Buteo regalis) is an important overwintering raptor at the Arsenal; its yearly occurrence and density have been roughly associated with estimated population densities of known prey animals (e.g. black-tailed prairie dog, (Cynomys ludovicianus) (M. Lockhart, pers. commun.).

OBJECTIVES

The objectives of this task are to:

1.) Estimate abundance, distribution, average home range, and habitat use of ferruginous hawks overwintering at RMA.

2.) Determine the effects of human disturbance on an avian scavenging guild consisting of buteos, eagles and magpies.

3.) Document the year-round abundance and habitat use of all falconiformes at RMA.

4.) Determine yearly variation in ferruginous hawk diets.

5.) Characterize ferruginous hawk communal roost sites on RMA.

This report summarizes field work conducted on RMA from June 1991 through November 1992.

METHODS

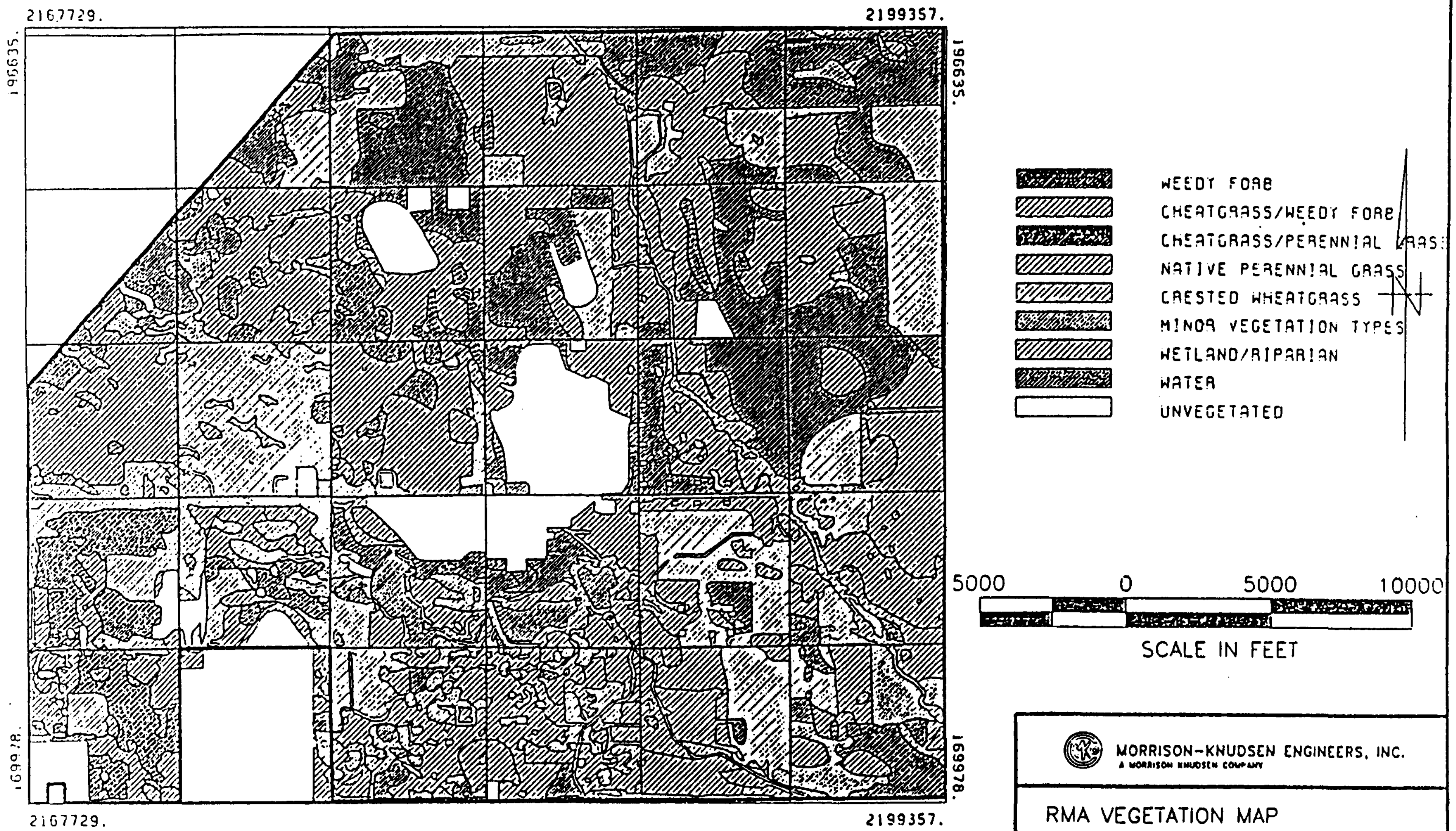
ROAD COUNTS

Twice monthly roadside surveys (Fuller and Mosher 1981, 1987) began on June 15, 1991. Surveys were conducted between 06:00 and 11:00 hours on days when visibility exceeded 1500 meters and wind velocity was less than 16 km/hour. Observations were conducted from a vehicle moving from 25 to 40 km/hour and all raptors observed within 400 meters of the road were recorded. During road transects we recorded weather (temperature, wind speed and direction, percent cloud cover, percent snow cover, and precipitation), start and finish odometer readings, start and finish times, location of bird (odometer reading, Township/range section, and map plot) distance to the bird (calculated from a map showing measured distances to perch sites), landscape composition, proximity to human disturbance (0-0.4, 0.4-1.0, and > 1.0 Km), bird behavior, and perch type.

The raptor road transect route (Figure 1) consists of 45 kilometers (approximately 28 miles) of maintained section roads within the boundaries of RMA. This transect has been subdivided into a series of 24 sample segments (lags) of equal length (1.6 km). Starting and stopping points for each lag roughly correspond to section roads. In order to maintain independence of observations, sample segments where search areas overlapped were eliminated. Each segment is treated as an independent sample plot with specific habitat and land use characteristics.

We determined habitat use by locating each raptor on a vegetation map (Figure 2) and recording dominant vegetation surrounding each bird observed. Landscape composition was classified and mapped according to vegetation type using methodology consistent with companion ecological studies currently being conducted on RMA. Landscape composition consisted of the following vegetation types:

- Shortgrass prairie (including sand dropseed and needle-and-thread grass)
- Shrub grassland (yucca and sand sagebrush)
- Weedy forb
- Crested wheatgrass
- Prairie dog town
- Wetland
- Woodland/Riparian
- Disturbed/Unvegetated
- Cropland



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RMA VEGETATION MAP

Figure 2

We then calculated the percentage (area) of each vegetation type within each road count segment. Each segment was annually ground checked to verify landscape classification and record changing landscapes (e.g. expanding prairie dog towns, remediation).

RADIO-TELEMETRY

Ferruginous hawks were captured, banded, equipped with radio transmitters, and tracked during fall and winter 1991/92 and again in fall 1992 (see Bloom 1987 for a review of capturing and handling techniques). Up to 8 radio-tagged birds were tracked for two 4-hour periods per week (systematic relocations) during its residence at the Arsenal (Andersen and Rongstad 1989). Home range size for each of these birds will be estimated using the minimum convex polygon approach (Mohr 1947, Southwood 1966) and areas of high use will be identified using the 50% harmonic mean activity area (Dixon and Chapman 1980). Additionally, as many radio-tagged birds as possible were visually relocated once per day, two to five days per week (random relocations) to help determine spatial distribution patterns of ferruginous hawks at the Arsenal.

Hawk distribution will be related to prey density (biomass) and vegetation characteristics through extrapolation from concurrent studies being conducted at the Arsenal with the aid of cross classification analyses (e.g., loglinear analysis) and stepwise regression analyses (Preston 1990).

DIET

Regurgitated castings were collected from beneath communal ferruginous hawk roosts from throughout RMA. These casting were placed in individual ziploc bags, identified by number, date and location then stored in a freezer at the Denver Museum of Natural History. Castings were collected from beneath the following ferruginous hawk roosts:

- SE 1/4, SW 1/4, Section 33
- SE 1/4, SW 1/4, Section 4

- SW 1/4, SE 1/4, Section 4
- SE 1/4, SW 1/4, Section 3
- NW 1/4, NW 1/4, Section 27
- Mid Section 22
- SW 1/4, SE 1/4, Section 24
- SE 1/4, NE 1/4, Section 9
- NW 1/4, NE 1/4, Section 11

Castings were processed according to methodology adapted from Marti (1987). Castings were dissected by hand and hair and vegetation teased away from bones, teeth, and feathers. Samples of all distinguishable hair types were mounted on microscope slides with a penetrating mounting medium (Cytoceal) for later identification according to Moore et al. (1974). Feathers, bones, teeth, and other identifiable remains were compared to museum reference collections and a mammalian skull key (Glass 1973) for identification.

Diet can be summarized by 1.) frequency of occurrence by number of each prey category in the total sample, 2.) frequency of samples (eg., castings) in which each prey category occurred, and 3.) relative contribution of the various prey types to the total biomass of prey consumed (Marti 1987). Analyses of ferruginous hawk food habits on RMA consist of both frequency of occurrence and relative biomass. Relative prey biomass will be determined from weight measurements by age class of prey species captured on RMA during companion studies (ie., small mammal and passerine). To calculate relative biomass of prey in the diet, mean weight of prey species by age class minus mean weight of unconsumed prey portion (eg., head, skin, and fat of prairie dogs) will be multiplied by frequency of occurrence of prey in castings and foraging observations.

ROOST SITE CHARACTERISTICS

Beginning in November, 1992, an additional roadside survey was conducted during dusk once every 2 weeks to determine hawk use and density at communal roosts. Communal roost sites identified during roadside surveys are mapped, photographed, and studied according to methodology adapted from Keister and Anthony (1983). Roost trees will then be measured after communal roosts have been seasonally vacated. Data collected from communal roosts will include:

1) tree species,
2) diameter at breast height (DBH),
3) height classification (0-23m, 24-30m, 31-38m, 39-46m)
4) structure classification,
5) number of roost trees within a communal roost,
6) protection from prevailing wind, and
7) proximity to roads and other man-made structures.

The size and structure of roost trees/stand will be compared to random non-roost trees/stands within a 1.6 km radius.

RESULTS

ROADSIDE SURVEYS

Forty-three roadside surveys were conducted between 15 June 1991 and 1 December 1992. Summer surveys indicate the presence of four species (red-tailed hawk, Swainson's hawk (Buteo swainsoni), American kestrel (Falco sparverius), and northern harrier (Circus cyaneus)) potentially nesting on the Arsenal, as well as occasional non-breeding ferruginous hawks. Cooper's hawks (Accipiter cooperii), turkey vultures (Cathartes aura), golden eagles (Aquila chrysaetos), and prairie falcons (Falco mexicanus). The number of ferruginous and red-tailed hawks counted during road surveys have markedly increased in September during fall migration. Migrating Ospreys (Pandion haliaetus) were occasionally observed.

Winter surveys show the presence of ferruginous hawk, red-tailed hawk, rough-legged hawk (Buteo lagopus), bald eagle (Haliaeetus leucucephalus), and golden eagle. Occasionally, northern harrier, American kestrel, merlin (Falco columbarius), prairie falcon, and peregrine falcon (Falco peregrinus) are observed.

Preliminary habitat analysis through June 1992 using a chi-square analysis (Neu et al. 1974) revealed that buteos, particularity ferruginous hawks, wintering on RMA do not use habitats in proportion to their availability. Ferruginous hawks tended to concentrate near prairie dog towns and shortgrass prairie; rough legged hawks occurred in more wooded areas; and red-tailed hawks occurred in all habitat types.

Preliminary comparison of 1991 and 1992 data, comparing results of road counts from June through November of each year reveals that the relative abundance of raptors using RMA has remained essentially stable. Only the relative abundance of two species has notably changed. The relative abundance of red-tailed hawk has increased 4.3 percent, while bald eagle abundance has decreased 3.0 percent over the same time periods in 1991 and 1992. Comparing road count data seasonally from 1991 to 1992 revealed the following:

Summer

- Ferruginous hawks occasionally observed in 1992 compared to no observations in 1991.
- Red-tailed hawk relative abundance and observations per transect were noticeably decreased in 1992.
- Swainson's hawk relative abundance increased in 1992, although observations per transect remained consistent.
- American kestrel relative abundance and observations per transect greatly decreased in 1992.
- Overall raptor abundance was greater in 1991.

Fall (migration)

- Ferruginous hawk relative abundance and observations per transect remained consistent.

- Red-tailed hawk relative abundance and observations per transect markedly increased in 1992.
- Swainson's hawk remained on RMA longer in 1991 resulting in an increase in observations per transect.
- Rough-legged hawks arrived earlier in 1991.
- American kestrel and northern harrier relative abundance and observations per transect remained consistent.
- Overall raptor abundance remained consistent.

A summary of roadside surveys are presented in Appendix A.

RADIO-TELEMETRY

Raptor trapping began in September 1991 and continued through January 1992 with a total of eight ferruginous hawks being trapped and equipped with transmitters during the winter of 1991/92 (Table 1). Two hawks trapped in early November immediately left the area and were not relocated. The remaining six hawks were intensively tracked until they migrated or lost the transmitter. The last radio-equipped hawk to depart the area was intensively tracked on 13 March 1992 and could not be located during a routine roll call on 14 March 1992 or subsequent intensive searching. The total effort expended and direct observation recorded on radio-tagged hawks for the winter of 1991-1992 were approximately 500 and 280 hours respectively.

Preliminary home range analysis using minimum convex polygons revealed that radio-tagged ferruginous hawks occupied relatively distinct home ranges in 1991/92 (Figure 3). These preliminary results suggest that RMA provides a central reference area or corridor for a regional concentration of ferruginous hawks wintering in the Denver metropolitan area.

Table 1. FERRUGINOUS HAWK BANDING RECORDS

BAND No.	FREQUENCY	DATE TRAPPED	AGE	LOCATION
1207-29107	164.589	10/2/91	HY	Sec. 29, RMA
1207-29106	164.703	10/2/91	SY	Sec. 32, RMA
1207-29031	164.561	11/14/91	SY	Sec. 19, RMA
1207-29033	164.354	11/14/91	SY	Sec. 5, RMA
788-17171	164.804	11/21/91	ASY	Sec. 9, RMA
1207-29108	164.400	12/14/91	SY	Sec. 9, RMA
1207-29109	164.301	1/14/92	SY	Sec. 30, RMA
788-17172	164.203	1/16/92	SY	Sec. 27, RMA
788-17173	164.096	11/19/92	HY	Sec. 9, RMA
788-17174	164.036	11/21/92	ASY	Sec. 9, RMA
1207-58768	164.276	11/21/92	ASY	Sec. 27, RMA
1207-58769	164.315	11/30/92	ASY	Sec. 9, RMA
788-17175	164.238	11/30/92	HY	Sec. 30, RMA
788-17176	164.380	11/30/92	SY	Sec. 9, RMA
788-17177	164.116	11/30/92	ASY	Sec. 9, RMA
1207-10922	164.340	12/1/92	ASY	Sec. 29, RMA
788-17178	164.162	12/1/92	ASY	Sec. 20, RMA
1207-58770	164.061	12/1/92	ASY	Sec. 29, RMA
1207-58771	164.082	12/2/92	HY	Sec. 10, RMA
788-17179	164. 362	12/4/92	HY	Sec. 9, RMA

Twelve ferruginous hawks were trapped on RMA between November 19 and December 4, 1992 and equipped with radio transmitters (Table 1). Tracking of radio-tagged hawks began immediately with each hawk being randomly relocated a minimum of twice weekly. Locations of randomly relocated hawks were marked on a 1:24,000 topographic maps and recorded by UTM to the nearest 10 meters. Additionally, eight radio-tagged hawks have been randomly selected for more intensive tracking consisting of a minimum of two 4-hour tracking sessions per week.

One suspected mortality of a radio-tagged ferruginous hawk was recorded in 1992. This occurred on 08 March 1992, when a field assistant triangulated on a signal in the midst of a prairie dog town at 124th and Peoria. The radio signal did not change during several hours of observation that continued past dark and no visual observations were recorded. Further investigation the following day (9 March) found feathers, including a patch of caudal skin and down feathers, scattered about a small area along with the partially chewed transmitter. Also found in the immediate area were two copper-coated B B's. No carcass, wings or tail feathers, other than the broken feather attached to the transmitter could be located. However, subsequent raptor trapping on RMA in October 1992 re-captured this same ferruginous hawk, confirmed by the federal leg band, and documented that the hawk was very much alive.

DIET

Regurgitated raptor castings were collected from beneath ferruginous hawk roosts in spring 1992, placed in ziploc bags, labeled and placed in a freezer at the Denver Museum of Natural History. To date 110 castings have been processed; separating identifiable materials, such as bones, teeth, and feathers from hair, for comparison to reference collections at the museum. Hair samples from each processed casting have been mounted on a microscope slide and clearly labeled. Initial identification of bones and teeth revealed diets consisting largely of prairie dogs and lagomorphs, with voles, deer mice, pocket gophers, and avian prey occurring less frequently. Further analyses of hair samples and identification of the more difficult bones will provide more complete results.

ADDITIONAL PLANS FOR 1993

We will continue roadside counts of raptors and collection of ferruginous hawk castings through December 1993.

We will continue monitoring of radio-tagged birds throughout their residency on RMA in 1993. Up to 15 ferruginous hawks will again be trapped in late fall 1993 and tracked through spring 1994.

We will analyze raptor habitat use of RMA and the surrounding area using a personnel computer Geographic Information System (GIS). Vegetation, landscape cover, raptor observation locations, perches, communal roost sites, disturbance types, and prey densities will be entered into separate layers of a GIS system allowing for analysis of data both visually and analytically.

The effects of human disturbance on raptors wintering on RMA will be analyzed using both roadside surveys and simulated human disturbance experiments. Human disturbance on RMA will be classified as high, medium, or low within the following disturbance types:

1) Physical (e.g., habitat destruction)
2) Audio
3) Visual

Criteria to be used for classifying human disturbance as high, medium, or low is presented in Table 2.

Table 2. Disturbance Type and Classification Criteria

DISTURBANCE	HIGH	MEDIUM	LOW
PHYSICAL	Habitat severely altered (structures, basins)	Habitat slightly altered (monitoring wells, mowing)	Undisturbed
VISUAL	Activity frequently within sight	Activity occasionally within sight	Activity unlikely within sight
AUDIO	Activity frequently audible	Activity occasionally audible	Activity rarely audible

Raptor abundance and distribution will be compared to levels of human disturbance using a chi-square goodness of fit test.

Simulated human disturbance of an avian foraging guild will be studied following methodology of Skagen et al. (1991). The hypotheses to be investigated during disturbance experiments consist of:

1) Temporal patterns of resource use are the same among guild members
2) Foraging guild members respond equally to human disturbance
3) The degree of sensitivity of the foraging guild to human disturbance corresponds to the size of the disturbance
4) Spacial and temporal patterns of resource use by guild members does not change in response to levels of human activity

Foraging stations will be established at three experimental stations on RMA in open prairie habitats with expansive views where human activity is infrequent. Carcasses of small mammals, prairie dogs, and lagomorphs obtained from agricultural control programs will be placed at foraging stations before first light. From a blind, foraging patterns will be recorded in the absence of human activity, and various simulated disturbances consisting of:

1) Single person on foot

2) Group of people on foot

3) Pickup truck

4) Bus

5) Heavy equipment

Responses of the various members of the scavenging guild will be measured by 1) the flushing distance of each guild member from the various disturbances, and 2) the quantity of food consumed in the absence of disturbance and the various disturbance treatments. Food consumption by species will be calculated following the methodology of Skagen et al. (1991). The quantity of prey consumed will be calculated by species *i* as: S*i* = (bird-minutes of feeding[2])*i* x bites per bird-minute of feeding)*i* x grams consumed per bite)*i*. For eagles, the value of 62.5 g/min, derived from foraging data of M.V. Stalmaster (in Skagen et al. 1991) will be used. Because no such values exist for ferruginous hawks or magpies, the number of bites per minute will be obtained from feeding observations. To determine prey consumption per bite, we will record the number of bites taken from pre-weighed prairie dogs by foraging ferruginous hawks and magpies, and then reweigh the carcass after each observation period.

From a blind we will record the use of prey stations by the foraging guild. At 10-minute intervals we will record the species, behavior, and distance from prairie dog carcasses (0-1 m, 1-5 m, 5-15 m, >15 m) of each individual at each station. For each observation area we will randomly conduct each of the six simulated disturbances. A minimum of 6 replicates of each disturbance type will be conducted from each foraging station. Analyses of guild members response to disturbance will be compared using chi-square goodness of fit tests and contingency tables. Quantity of prey consumed in the absence of human disturbance and in the presence of the various disturbances will be compared using students t-test.

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APPENDIX A

Summary of Raptor Roadside Surveys Conducted on RMA
1991/1992

12 11 92

RAPTOR ROAD COUNTS

1991

DATE	FH	RT	RL	SH	NH	Uk B	BE	GE	Uk E	MER	AK	PG	PF	Uk F	CH	SS	OS	TOTAL
6/15/91		5		6	1	1					14							27
6/30/91		5		6							19							30
7/14/91		6		5		1					26							38
7/28/91		7		16							7							30
8/11/91		6		12							8							26
8/25/91	5	12		13	1	1					3				1			36
9/7/91	1	8		8	2						4							23
9/13/91	10	13		11	2						2							38
9/21/91	9	11		11	1						9							41
10/6/91	8	15			1	5		1			2	1						33
10/20/91	11	17	3	1	2	2	1	1					1					39
10/26/91	13	18	4		4	1		2					1					43
11/16/91	10	5	3		2	3		1										24
11/23/91	13	10	1			2	3	1		1								31
11/30/91	13	7	6		2	2	15					1						46
12/7/91	20	6	5				6				1							38
12/21/91	17	11	5				6	3										42
TOTALS	130	162	27	89	18	18	31	9	0	1	95	2	2	0	1	0	0	585
PERCENT	22.22%	27.69%	4.62%	15.21%	3.08%	3.08%	5.30%	1.54%	0.00%	0.17%	16.24%	0.34%	0.34%	0.00%	0.17%	0.00%	0.00%	100.00%

RAPTOR ROAD COUNTS

1992

DATE	FH	RT	RL	SH	NH	Uk B	BE	GE	Uk E	MER	AK	PG	PF	Uk F	CH	SS	OS	TOTAL
1/4/92	11	10	6				1	1	1		1							31
1/18/92	7	1	2				3	1					1	1				16
1/25/92	20	4	3				4				1							32
2/2/92	16	8	7				15	1										47
2/15/92	5	7	3			1	18											34
2/29/92	6	7	2				5	1										21
3/14/92	6	9	3				2				5		1					26
3/31/92	2	6			1	1		1			17							28
4/12/92		9		7							28							44
4/28/92		1		9		1					11							22
5/11/92		2		5	1						7							15
5/26/92		3		8				1			2							14
6/6/92	1	2		5							8							16
6/21/92		3		5							5							13
7/3/92		2		7		1					19							29
7/22/92		3		13							7							23
8/5/92		7		13	1			1			11							33
8/18/92	2	7		12							7							28
9/6/92	4	23		13	1	2		1			5						1	50
9/19/92	2	20		4		1					10		2					39
10/7/92	9	17			1													27
10/18/92	12	13			3	1		1										30
10/31/92	12	16	1		2		1	1					1					34
11/16/92	7	8	4		2		1			1								23
11/28/92	24	7	7			1	1	1					1					42
																		0
TOTALS	146	195	38	101	12	9	51	11	1	1	144	0	6	1	0	0	1	717
PERCENT	20.36%	27.20%	5.30%	14.09%	1.67%	1.26%	7.11%	1.53%	0.14%	0.14%	20.08%	0.00%	0.84%	0.14%	0.00%	0.00%	0.14%	100.00%

RAPTOR ROAD COUNTS - SUMMER 1991

DATE	FH	RT	RL	SH	NH	Uk B	BE	GE	Uk E	MER	AK	PG	PF	Uk F	CH	SS	OS	TOTAL
6/15/91		5		6	1	1					14							27
6/30/91		5		6							19							30
7/14/91		6		5		1					26							38
7/28/91		7		16							7							30
8/11/91		6		12							8							26
TOTALS	0	29	0	45	1	2	0	0	0	0	74	0	0	0	0	0	0	151
PERCENT	0.00%	19.21%	0.00%	29.80%	0.66%	1.32%	0.00%	0.00%	0.00%	0.00%	49.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%

RAPTOR ROAD COUNTS - FALL 1991

DATE	FH	RT	RL	SH	NH	Uk B	BE	GE	Uk E	MER	AK	PG	PF	Uk F	CH	SS	OS	TOTAL
8/25/91	5	12		13	1	1					3				1			36
9/7/91	1	8		8	2						4							23
9/13/91	10	13		11	2						2							38
9/21/91	9	11		11	1						9							41
10/6/91	8	15			1	5		1			2	1						33
10/20/91	11	17	3	1	2	2	1	1					1					39
10/26/91	13	18	4		4	1		2					1					43
TOTALS	57	94	7	44	13	9	1	4	0	0	20	1	2	0	1	0	0	253
PERCENT	22.53%	37.15%	2.77%	17.39%	5.14%	3.56%	0.40%	1.58%	0.00%	0.00%	7.91%	0.40%	0.79%	0.00%	0.40%	0.00%	0.00%	100.00%

RAPTOR ROAD COUNTS - WINTER 1991-92

DATE	FH	RT	RL	SH	NH	Uk B	BE	GE	Uk E	MER	AK	PG	PF	Uk F	CH	SS	OS	TOTAL
11/16/91	10	5	3		2	3		1										24
11/23/91	13	10	1			2	3	1		1								31
11/30/91	13	7	6		2	2	15					1						46
12/7/91	20	6	5				6				1							38
12/21/91	17	11	5				6	3										42
1/4/92	11	10	6				1	1	1		1							31
1/18/92	7	1	2				3	1					1	1				16
1/25/92	20	4	3				4				1							32
2/2/92	16	8	7				15	1										47
2/15/92	5	7	3			1	18											34
2/29/92	6	7	2				5	1										21
TOTALS	138	76	43	0	4	8	76	9	1	1	3	1	1	1	0	0	0	362
PERCENT	38.12%	20.99%	11.88%	0.00%	1.10%	2.21%	20.99%	2.49%	0.28%	0.28%	0.83%	0.28%	0.28%	0.28%	0.00%	0.00%	0.00%	100.00%

RAPTOR ROAD COUNTS - SPRING 1992

DATE	FH	RT	RL	SH	NH	Uk B	BE	GE	Uk E	MER	AK	PG	PF	Uk F	CH	SS	OS	TOTAL
3/14/92	6	9	3				2				5		1					26
3/31/92	2	6			1	1		1			17							28
4/12/92		9		7							28							44
4/28/92		1		9		1					11							22
5/11/92		2		5	1						7							15
5/26/92		4		8				1			2							15
TOTALS	8	31	3	29	2	2	2	2	0	0	70	0	1	0	0	0	0	150
PERCENT	5.33%	20.67%	2.00%	19.33%	1.33%	1.33%	1.33%	1.33%	0.00%	0.00%	46.67%	0.00%	0.67%	0.00%	0.00%	0.00%	0.00%	100.00%

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RAPTOR ROAD COUNTS - SUMMER 1992

DATE	FH	RT	RL	SH	NH	Uk B	BE	GE	Uk E	MER	AK	PG	PF	Uk F	CH	SS	OS	TOTAL
6/6/92	1	2		5							8							16
6/21/92		3		5							5							13
7/3/92		2		7		1					19							29
7/22/92		3		13							7							23
8/5/92		7		13	1			1			11							33
8/18/92	2	7		12							7							28
TOTALS	3	24	0	55	1	1	0	1	0	0	57	0	0	0	0	0	0	142
PERCENT	2.11%	16.90%	0.00%	38.73%	0.70%	0.70%	0.00%	0.70%	0.00%	0.00%	40.14%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%

RAPTOR ROAD COUNTS - FALL 1992

DATE	FH	RT	RL	SH	NH	Uk B	BE	GE	Uk E	MER	AK	PG	PF	Uk F	CH	SS	OS	TOTAL
9/6/92	4	23		13	1	2		1			5						1	50
9/19/92	2	20		4		1					10		2					39
10/7/92	9	17			1													27
10/18/92	12	13			3	1		1										30
10/31/92	12	16	1		2		1	1					1					34
TOTALS	39	89	1	17	7	4	1	3	0	0	15	0	3	0	0	0	1	180
PERCENT	21.67%	49.44%	0.56%	9.44%	3.89%	2.22%	0.56%	1.67%	0.00%	0.00%	8.33%	0.00%	1.67%	0.00%	0.00%	0.00%	0.56%	100.00%

RAPTOR ROAD COUNTS - WINTER 1992-93

DATE	FH	RT	RL	SH	NH	Uk B	BE	GE	Uk E	MER	AK	PG	PF	Uk F	CH	SS	OS	TOTAL
11/16/92	7	8	4		2		1			1								23
11/28/92	24	7	7			1	1	1					1					42
																		0
TOTALS	31	15	11	0	2	1	2	1	0	1	0	0	1	0	0	0	0	65
PERCENT	47.69%	23.08%	16.92%	0.00%	3.08%	1.54%	3.08%	1.54%	0.00%	1.54%	0.00%	0.00%	1.54%	0.00%	0.00%	0.00%	0.00%	100.00%

Figure 1

Raptor Roadside Surveys 1991

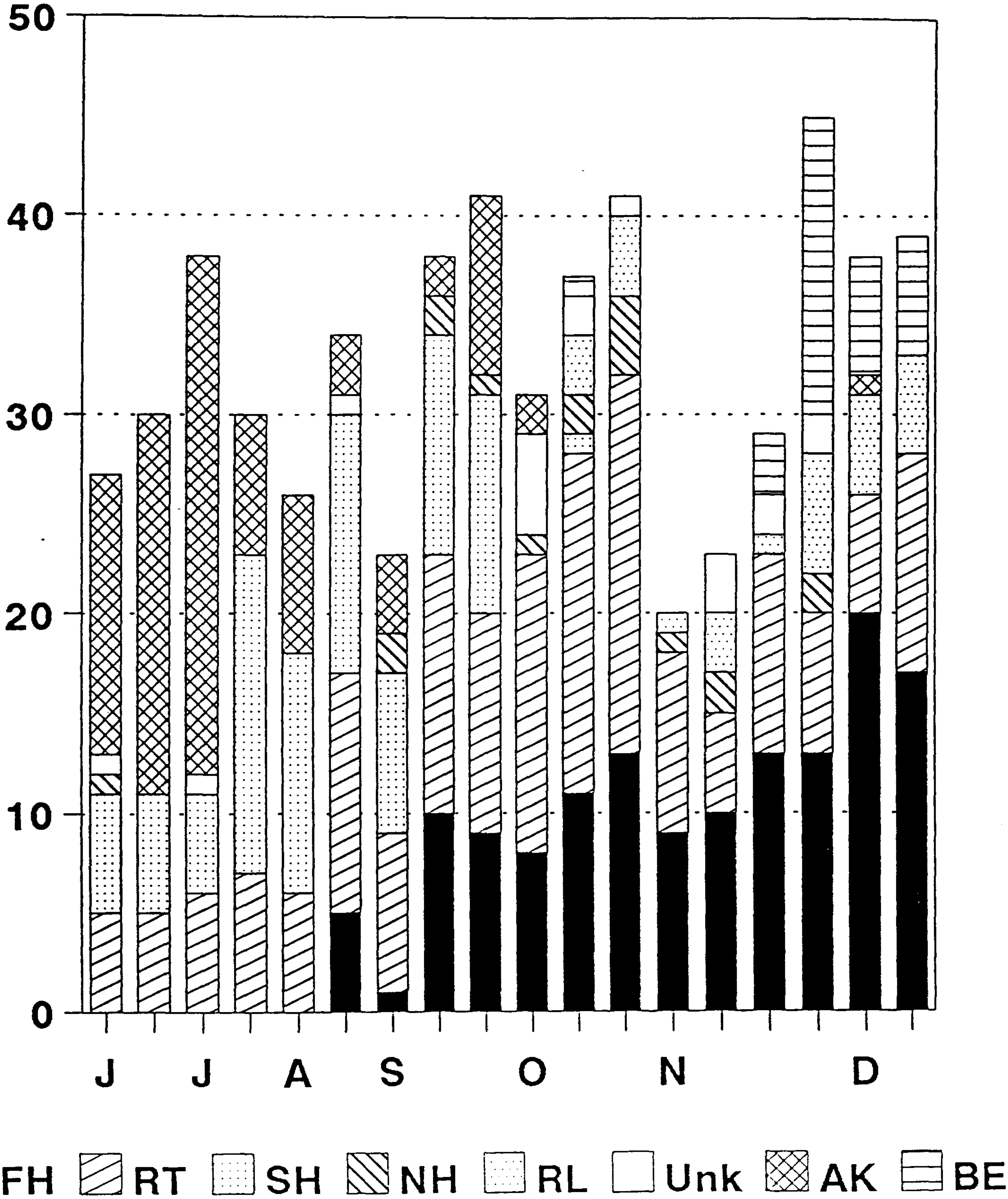
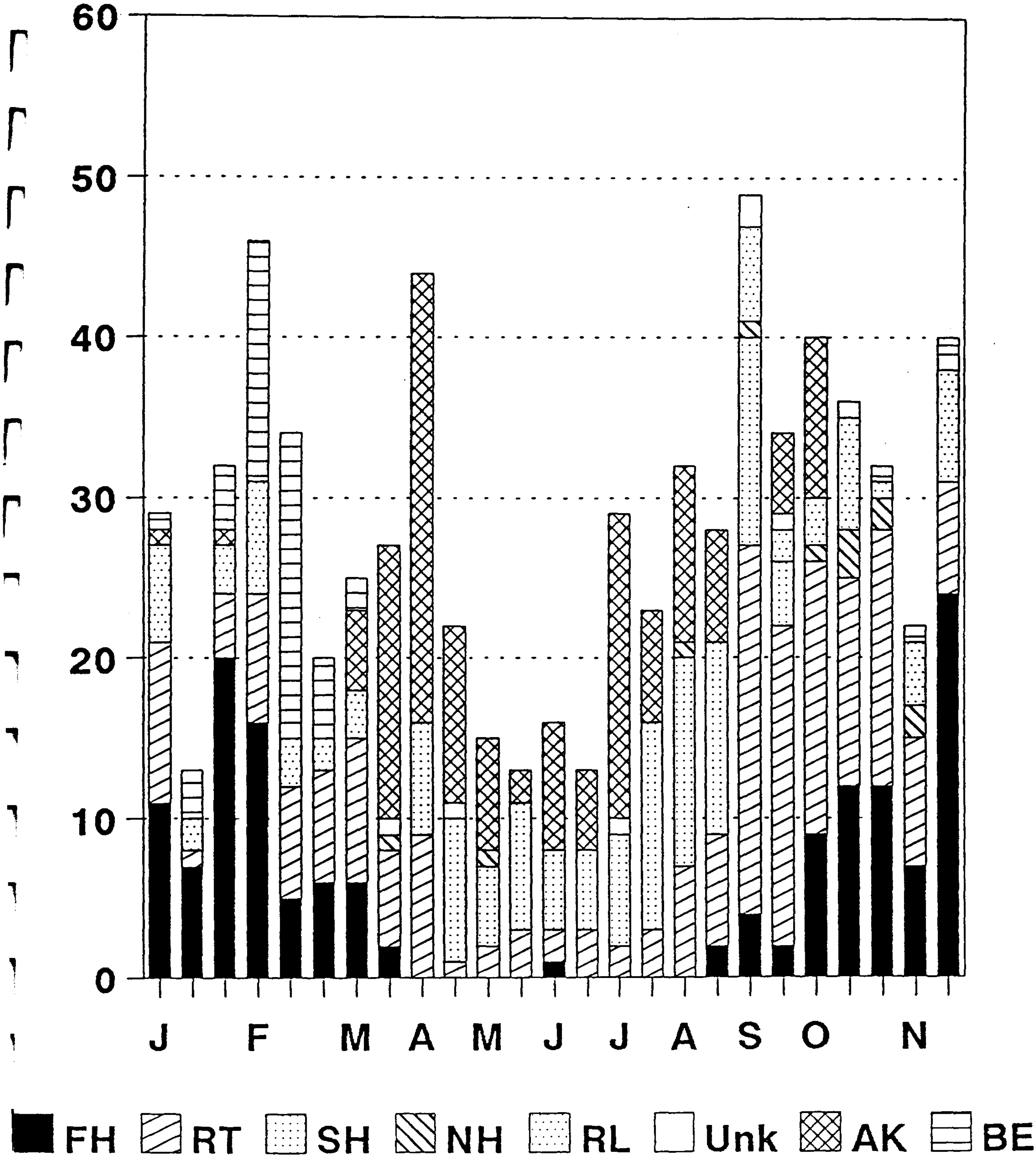


Figure 2

Raptor Roadside Surveys 1992



DOCUMENTATION AND INTERPRETATION OF SELECTED WILDLIFE HABITAT RELATIONSHIPS AT THE ROCKY MOUNTAIN ARSENAL

TASK FIVE: VIDEO

David Baysinger
TV Production

and

Charles R. Preston
Department of Zoology

Denver Museum of Natural History
City Park, Denver, Colorado

1992 Footage Log

TAPE 92-06B

START: ROCKY MOUNTAIN ARSENAL--U.S. ARMY/U.S. FISH AND WILDLIFE SERVICE PROJECT Zoology Dept. DATE: June 5, 1992
PHOTOGRAPHER: D. BAYSINGER
PRINCIPAL ACTIVITY: "FLY OVER" HELICOPTER SHOTS OF ENTIRE RMA WITH GATES RUBBER COMPANY TWIN-STAR

START TC:
00:00 Departure from Stapleton airport north across runways
00:22 Crossing Sand Creek and National Weather Service
00:40 Cross I-70 with morning sunlight
00:55 Business along Havana
01:00 Move from pilot and front view to 2:00 position with businesses along Havana st.
01:22 RMA property Sec. 11 northbound
02:00 Entering Sec.2 with Lake Mary in picture (smooth)
02:17 Crossing 7th Ave. turning east across White House Sec. 2
02:45 South Plants eastbound entering Sec. 1
03:25 South Plants and site of old Hydrazine Plant
04:05 First Creek along 7th Ave. Crossing into Sec. 6
04:39 Eagle Watch area in Sec. 5 (good light looking SE
04:45 Zoom into Eagle Watch
05:11 Southbound with Eagle Watch west of chopper
05:45 Westbound along south edge of Sec. 5 w/wetlands

06:07 Good long shot of first creek and Bald Eagle roosts
06:23 Crossing into Sec. 6
07:04 Crossing into Sec. 1 with good views of South Plants and Upper Derby Lake with good sun on trees (raking from east).
07:53 Crossing into Sec. 2 and shot of deer (hard to see)
08:00 Good shot of creek toward Lake Ladora. (water smooth with cloud reflections and green shores
08:25 Pelicans in Lake Ladora
08:58 Sec. 11 looking southbound from north edge
09:16 Clumps of trees and open spaces in Sec. 11
09:37 Sec. 12 more of same with good sun striking low
09:45 Small lake (followed) with pretty edging
10:21 Sec. 7 wetlands area with good color on vegetation
10:47 Sec. 6 with good shot of lake to SE showing limit of housing to the south with creek entering RMA property from SE

11:50 South along Sec. 6
12:15 West with 2 o'clock position showing Sec. 6
13:03 Crossing to south half of Sec. 12 w/nice view to South Plants to the north and lakes area.
13:25 Shot inside chopper to Barry Bennett and pilot
13:33 Swing out to Reserve armory and into Sec. 11
14:10 Crossing Stapleton 35 right runway
14:45 Into Sec. 9 with good shot of raptor roosts midway north
15:10 Views of SW end of Sec. 9 and right turn to follow Quebec
15:30 North along Quebec showing proximity of housing to RMA

15:47 Right turn to Eastbound in Sec. 4
16:11 Motor pool area and USFWS Hdq.
16:25 Into Sec. 3
16:40 Visitor's Center
17:00 180 degree turn to westbound along south edge of Sec. 34
17:30 Into Sec.. 33 with views toward Commerce City housing
17:39 Zoom to Hawk nests north side of 7th ave.
18:10 North turn...then east turn to see north edge of Sec. 33
18:38 View to horizon over Sec. 33 showing 7th ave., old railroad and vegetation all along way
19:00 180 degree turn to follow south edge of Sec. 27 (westbound) with diagonal road in distance.
19:20 Turning with pump buildings in view Sec. 28
21:10 Entering Sec. 23 eastbound
21:18 Fly-over purina bldg north of diagonal, then up to show pump area of wells in Sec. 22

22:07 Sec. 23 and zoom to site of old farmhouse or possible well area (land green w/signs of earlier agricultureal use
22:18 Begin very good shots of wells and pump house during cross to Sec. 24
23:14 Into north edge of Sec. 19
23:55 Entering north edge of Sec. 20
24:30 Turning corner to southbound along raceway with good shots all the way to downtown Denver
25:15 Westbound south edge of Sec. 20 (along 9th ave.) (good vegetation views with sunlight low from the east.

END OF TAPE 92-06B 6-5-92

TAPE 92-07B

START: ROCKY MOUNTAIN ARSENAL--U.S. ARMY/U.S. FISH AND WILDLIFE SERVICE PROJECT Zoology Dept. DATE: June 5, 1992
PHOTOGRAPHER: D. BAYSINGER TAPE #2 of shoot
PRINCIPAL ACTIVITY: "FLY OVER" HELICOPTER SHOTS OF ENTIRE RMA WITH GATES RUBBER COMPANY TWIN-STAR

START TC: 00 hrs.
00:30 In Sec. 29 flying along north edge with many land disturbances, including freshly plowed field along east side. Very green following nearly 2 weeks of rain.

01:12 Flying south along plowed field with North Plants in background. Also mountains and storm front in picture.
01:45 Westbound on 8th avenue with down shot of huge prairie dog town, green from rains. Easy to see "territories".
02:22 Enter Sec. 30 westbound with more land disturbances approaching First creek. View of North Plants with warm sun from east against white buildings. (long passage shot)
03:00 Entering Sec. 25 with North Plants in full view against black sky to the north. Storm front is 10 miles off.
03:30 Incinerator with holding tanks from 1 mile

03:43 Entering Sec. 26
05:07 180 turn to eastbound in Sec. 35 travel toward Basin "A" neck area along north side of section.
05:22 Over north edge of Sec. 36 with horizon view and South Plants at 1 mile distance.
05:42 Down to scrap equipment yard
05:58 Enter Sec. 31 eastbound with tree bunches, creek and onto material holding yards.
06:30 Enter Sec. 32
06:45 Down shot of large prairie dog town (same as 1:45 above)
08:10 Right turn to follow track to First creek and Eagle roosts. Down shot over cottonwood trees on creek with light coming light green through branches.

09:00 Back to west path along 7th avenue storage warehouses.
09:15 Enter Sec. 36
09:35 Down view of South Plants and stacks and tanks
09:50 Up to west end of Basin "A" and firehouse
09:56 Cross into Sec. 35
10:15 View of White House (not stable, chopper in left turn)
10:33 Fly over of Mary Lake and Vistor Center
10:50 Downtown Denver with rough shot and pullback to Sec. 2
11:03 Eastbound in Sec. 11
11:22 Enter Sec. 12
11:35 Beautiful lake again in Sec. 12
12:12 Sec. 12 looking north toward South Plants and black cloud wall of approaching storm.
12:32 Lakes (small) and reflected clouds (very pretty)
13:55 East toward new airport across Sec. 6

14:09 Farmstead just outside of east border of RMA
14:17 Large wheat field and plowed ground showing comparative value of agriculture areas and drainages.
14:50 First of new airport construction. Miles of open ground.
15:02 Scraper blowing black smoke on "haul road"
15:13 Water holding pond west of new tower
15:51 New terminal building with 390 ft. tower
16:06 Moving around north side of new tower with mountains coming into view in background. More new terminal space with underground train tunnels in view. Black sky in background!
16:55 Large terminal where "awning" will go. Swing to west showing all terminals and tower to north with black sky in background. Huge operation. Shows change from wildlife "sanctuary" feel of RMA to stripped land of major airport.

18:06 Back westbound over farmland and green
18:50 Storm look under clouds now with pilot looking
19:41 Back over RMA over Sec. 7 and southwest to Stapleton
21:41 Over U.S. Army Reserve base
22:35 I-70 fly over with city center and mountains in back
23:05 Current airport with clouds in back and sun on Mt. Evans
23:24 Runways and plane landing under chopper
23:39 Pullback to show downtown over runway 8L
23:57 Stapleton looking NW from Stanley aviation
24:11 Approach to Gates hanger
25:00 Landing

END OF TAPE 92-07B June 5, 1992

TAPE 92-40

ROCKY MOUNTAIN ARSENAL PROJECT   ZOOLOGY DEPARTMENT 10/20/92
Rodent and Song Bird projects   John Boone, Dale Wills, Rob DeBaca and Fitsimmons Army Medical group

TCR 00:00:00

00:05	Rob and Army Med team in NW section of arsenal running small rodent trapping operations.
00:09	Good CU of Harvest Mouse in hand
00:45	Mouse jumps away and team scurries to try to re-capture
00:55	DeBaca calls group with one in trap....they join him
01:40	Ready for ear clip (blocked)
01:50	Rob holds mouse on scale for MS
02:12	Faces of Army personnel including Major Tom Gargan
02:35	Asking about site designation to put on ear samples
03:00	New site and walk up on group with new mouse
03:20	Weighing of another harvest mouse
03:45	Reall CU of harvest mouse with tweezers on ear
04:00	Good ear clipping showing piece of ear on sissors
04:15	Rob walks past alone on way to another site
04:31	Sunrise shot with group in silouette shot (good color)
04:45	More sunrise with Rob in front of sun. Meadow Lark calls
05:18	Good sun blocked shot of team working. Breath shows in sunlight as they prepare to take ear sample
06:20	DeBaca walkes across camera to new site Got one more
07:20	Another good shot of ear sample being taken
08:08	Samples being put on dry ice in cooler
08:25	LS of group in field
08:30	Ground stable shot of group in "grassland" environment
09:40	Tom Gargan and Rob DeBaca hold in field meeting
10:00	More of same with another Harvest Mouse
10:30	Best weighing shot yet in sunlight
11:16	Both DeBaca and Gargan taking notes
12:14	DeBaca checking notes back at roadside then tilt to large number of traps in carrier. Cooler containing samples also visible.
12:43	View across field of north plants area
12:55	Vew to SW with army team about 40 yards away and Denver downtown tall buildings and mountains in background
13:00	Pan right through open field to Rob who is working on new trap
14:40	Good shot of ear sample being put in chemicals and then into vile. See ear chunk float to bottom!
15:10	Record keeping
15:50	LS of Rob and Army group in field using long lens
18:00	Dale Wills working bird transect at 8:30 a.m. MDT under departing jets.
18:25	He says, "Not a lot of bird singing going on in the fall"
18:37	Walking and talking, little audio usable except for

background cover under interview footage. Picture good
18:57 Hills silouetted against sun with binos up ... looking
19:35 Says, ..."been such a nice fall" ... as he walkd
20:00 Watching through binos with city denter in background
20:18 Good CU of face as Dale looks thru binos
20:38 Tilt down from horizon shot to grass in front of camera
20:50 good tripod shot, plane taking off and Dale walking in front of camera. Lots of noise
21:24 Dale opens notebook and looks
21:45 Dale walks far from camera and looks across field
22:00 Dale with binos then pan left ot field where he's looking
22:23 Tilt down to stake with yellow paint stripe
22:49 Ground level shot of grass and Dale standing 20 years away
23:02 Dale telephoto then pullback to grass. (Nice light)
23:28 Opens notebook
23:30 Camera moves toward Dale through grassland
23:45 Camera follows as Dale Wills walks to new stake

24:06 Tripod pictures of disturbance test area photoed earlier during plowing cycle. 10/20/92 shots show results of mowing also. View to the west (toward Flatirons)
24:30 Red flag waving in breeze then zoom to closer shot
24:50 Pan right to left showing near "native" or untouched grass and plowed and mowed area.
25:20 Right pan of same area with downtown Denver buildings in far distance
25:30 CU of grass mowed just in front of camera...zoom to closer
25:50 LS of mowed area (all brown now)
26:00 Rack focus of near tall grass then focus on demarcation line in distance with flags
26:24 Downtown Denver with mowed area in foreground...pullback
26:45 Incinerator with long lens then pullback as researcher's truck passes on roadway
27:02 Camera follow rodent team's pickup left to right
27:13 Same truck travels further down the road (good follow)
27:28 Good shot of red flag then pullback to mowed area

27:42 END OF TAPE 92-40

TAPE 92-49

ROCKY MOUNTAIN ARSENAL PROJECT   ZOOLOGY DEPARTMENT 6/15/92
Rodent and Song Bird projects   ** Summer tilling **
Location near tilled plot in song bird transect
TCR 00:00:00

00:05	Bars and voice ID
00:12	LS of roadway with car passing. Mostly native grass
00:30	CU grass heads in breeze
01:06	Static shot of 5 bottom plow (horizon in background)
01:11	Pan right to Ford tractor
01:19	Downtown Denver with pullback and pan left to plot before plowing. View is to the southwest. (haze in view)
01:53	Flags indicating limits of mowing and now plowing
02:03	Mowed area vs. non-mowed area with multiple shots
02:30	CU of mowed clumped grasses
02:34	Tractor comes toward camera over the hill with downtown Denver in background. Long telephoto (good color)
02:55	Tractor toward camera on first tilling pass. View southwest toward tall buildings just seen over plowed furrows
03:30	Good CU of tractor pass and lowering of plow shares
03:52	Shows at close range how dirt is actually turned over
04:10	CU view of "cut" in ground from first run of plow. More shots of turned land with tilt down to dirt and mix of grass and dirt.
04:33	Camera in furrow looking out at "cut" into ground
04:40	Tractor passes with plow up and drives away
04:55	Pan from receeding tractor to plowed ground
05:07	ECU of chunk of soil turned over with grass roots exposed
05:15	Another like shot but greater distance. Grass roots hang open in the wind
05:25	Plowed expanse with soil on left and mowed grass on right then pan right to grass and hold.
05:45	Pan right to left from grass to disturbed area.
05:55	Rack focus to plowed ground and back
06:09	TEMPORARY END OF TAPE 92-49

TAPE 92-50

ROCKY MOUNTAIN ARSENAL PROJECT   ZOOLOGY DEPARTMENT   11/30/92
Ferruginous Hawk Study #1   Dr. Charles Preston, Ron Beane, Rob DeBaca   Photographer: D. Baysinger   RMA

TCR 11:00:00

00:05	Morning 5:55 a.m. south of Fish and Wildlife Hdq. looking west as Preston, Beane and DeBaca prepare to bait trapps for the day's activity. City lights shine in backgound and car headlights cast blue paths on snow lying on the roadway.
00:37	Voices heard as plans for locations are made.
00:50	Beane: "A lot of birds out in the northeast!"
01:00	Beane gets map and both Preston and Beane determine where to place traps near "big prairie dog town".
01:42	Sunrise along roadway and tree line (very pretty)
01:57	Telephoto compression of relative "heat" waves moving across roadway. View to the east with car and trees and snow.
02:08	Ferruginous hawk in tree facing rising sun (stable shot)
02:36	View northwest as 2 Ferruginous hawks sit atop poles
02:40	Long's Peak in background
03:37	LS of treeline roost area (barely long enough for editing). with 5 sec. preroll
03:42	MS of Ron Beane departing truck with hammer to set stake for placement of trap.
04:11	Ron carries wire mesh to site from truck and places it in the snow. CU placement in the snow
04:50	CU of adjusting snares on trip grid
05:40	Beane gets "road kill" jack rabbit from truck and places it on the trap area, ties it down and sprinkles snow over site.
06:48	Ferruginous hawk sits in field (hand held camera) Believed that he is trapped. Shot from inside truck through windshield. Beane drives to trap.
07:28	Ferruginous hawk breaks free of trip and flies!
07:33	Good Ferruginous hawk flight and landing thru windshield
07:48	Ferruginous hawk sits on top of pole to watch placement of trap. Seems interested, sure.
08:00	Ron Beane resets metal trap and sprinkles snow over site
08:11	CU of trap in snow
08:56	Beane runs toward trapped Ferruginous hawk through snow covered field. Shot from inside of truck
09:12	Baysinger arrives at capture site. Bird's wings in defensive posture. (good focus and colors
09:57	CU of bird's head and eyes (not a happy camper)
11:30	CU hawk talons.
11:33	Beane walks toward truck with hawk under one arm (walking shot with truck and mountains in background)
11:42	At truck getting radio for call. Hawk held closely

11:47	Dr. Preston has hawk and walks toward door of laboratory
12:18	CU of Ferruginous hawk with face covering screen.
12:29	CU eye
13:14	Preston: "Well now that we've trapped him......."
14:30	Taking weight measurement
15:06	Banding (audio here is usable, but distant)
16:56	Prep for tansmitter installation. CU transmitter.
17:25	CU of tail feather preparation with shot of feet
17:45	Wide shot of room and walk to table where bird is being worked. Beane and Preston working (imagine)
18:20	Beane does transmitter test and talks through it. (can hear beeps on soundtrack)
19:45	Attaching transmitter on tail feather
19:50	CU cut aways of Preston
23:10	More process of transmitter afixing with cuts to both researchers. (lots of shots for editing final sequence)
24:00	Shots from high on chair looking down at procedure.
24:10	CU feet and talons
25:11	Transmitter in position. Than mixing of epoxy
25:32	Application of epoxy. (good angle for good view)
28:10	Measuring while epoxy sets. Talon length, beak, wing
29:00	Preston records in notebook
29:05	Preston emerges from door and carries bird to release area south of F & W building.
29:30	MS...3--2--1 release and flight to tree (nice light)
29:56	Researchers walk away from site

29:58 END OF TAPE 92-50

TAPE 92-51

ROCKY MOUNTAIN ARSENAL PROJECT ZOOLOGY DEPARTMENT 12/1/92
Ferruginous Hawk Study #2 Dr. Charles Preston, Ron Beane, Rob DeBaca Photographer: D. Baysinger RMA

TCR 12:00:00

00:05 In Fish & Wildlife Service laboratory at RMA as Preston and Beane prepare to examine a Ferruginous hawk.

00:15 Dr. Preston describes purpose of the examination and what procedures will be done in the nest minutes. (good audio from radio microphone)

00:30 Continues to describe research goals regarding the Ferruginous hawk research at RMA.

01:35 Preston: "This looks like a fairly small Ferruginous hawk".

01:45 Preston: "There are no obvious differences between male and female Ferruginous hawks...other than the size".

02:18 Preston: "When the eye is covered generally, just like the falconer's hood, the bird is pretty quiet".

02:40 Weighing bird

03:00 Preston: "This one is 2400 grams". (weight of bird)

03:41 Preston: "Now the next thing we are going to do is put a little lock-on band"..........

04:30 Describes banding and data base information and reasons.

05:00 Puts band on Ferruginous hawk.

06:20 Preston: "Now this bird may not be thrilled with us right now, but he's not hurt!".

06:47 Preston: "We're measuring the tail here all the way from the base all the way to the tip".

06:55 Much good discussion of process here scattered with pictures. ((listen to tape completely before editing!!!))

08:00 Preston: "Just the information on measurements and plumage characteristics and some of these things might give a clue as to where this bird breeds. We don't know as a matter of fact right now with any certainty what kind of geographic variation there is......."

09:15 Measuring feet, talons (with full description of process)

11:30 Preston: "What Ron is going to do.....is to afix a radio transmitter to the tail feather......"

11:42 Preston: "What happens, the transmitter will stay...it has a transmitting life of about 6 months. It probably won't stay with the bird for quite that long though. Because at about that time or before that time this bird will molt those tail feathers one at a time and when that central tail feather is molted, the transmitter will be lost with it. But it's done its work for us by that time".

12:07	Bird is startled!
12:26	CU bird head
12:35	CU transmitter
12:40	Beane: "This is the transmitter and until now...this little groove goes onto the tail" (audio bad)
13:01	Beane does transmitter test with beeps in background.
13:15	Beane puts transmitter on bird's feather
13:17	Preston: "Everybody asked where it gets the name Ferruginous. Well Ferruginous comes from the same latin word for iron, ferris, which esentially means the color of iron. ... And you see that throughout the Ferruginous hawk here on the legs and .... the striking color is Ferruginous, this reddish brown".
14:56	Preston: "The trickiest part of afixing this transmitter is making sure that we don't "muss" the feathers".
16:00	Installation of the transmitter (probably it's a better view on tape 92-50)
16:55	Preston: "....the less time with us, the less stress on the bird".
17:40	ECU feet with talons
18:00	Beane tells how tansmitters have evolved smaller and smaller so that now, they can be put on feathers.
19:00	Mixing epoxy
21:01	Preston: "We are also using a technique or a trap type called a Balcha tree traps. The B-C traps, modified from an eastern Indian design, we use monofilament nooses in a cage. The cage filled with a pigeon ..... again it hold the bird without injuring him".
22:10	More good commentary about trap types and procedures.
22:33	Ready for release of Ferruginous hawk in the northeast corner of the RMA. (Wind noise over parts of tape)
22:45	CU of Ferruginous hawk held by Dr. Preston.
23:00	Pullback of Preston ready for release.
23:20	More still pictures.
23:33	R E L E A S E of Ferruginous hawk
23:35	Camera follows Ferruginous hawk as it moves west into a sunset sky and rejects several landing sites finally landing in a fallen snag.
24:07	Ferruginous hawk shakes feathers back into shape
24:13	END OF TAPE 92-51

DOCUMENTATION AND INTERPRETATION OF SELECTED WILDLIFE HABITAT RELATIONSHIPS AT ROCKY MOUNTAIN ARSENAL

TASK SIX: TEACHER RESOURCE GUIDE

BY

Carol Kampert, Task Supervisor

Department of Education

and

Dr. Charles R. Preston, Project Director

Department of Zoology

Denver Museum of Natural History

City Park, Denver, Colorado

1992 Annual Progress Report

31 December 1992

INTRODUCTION

In 1992, much progress was made on the Teacher Resource Guide for the Rocky Mountain Arsenal. The objectives of the guide are to introduce Colorado educators and students, grades 4-12, to the unique wildlife, ecological diversity, and history of land-use at the Arsenal. The guide is also designed to involve students and teachers in the ethical and environmental issues connected with cleanup operations and wildlife management at the site.

A series of meetings with U.S. Fish and Wildlife Service representatives resulted in further decisions about format, content, marketing, and distribution of the guide. Meetings were also held to determine to copyright and printing rights of the U.S.F.W.S. The author also met several times with the new U.S.F.W.S Education Specialist to plan integration of on-site and off-site activities in the guide.

The first draft of the guide was sent to several reviewers, including school teachers at different grade levels, museum curators and educators, and a Colorado historian/author.

As outlined in the 1991-1992 Task Plan and Budget, 1000 copies of the Guide will initially be printed. The guide will consist of 96 pages (48 pages printed on both sides) in a loose-leaf binder with a 2-color cover. It will include interdisciplinary activities, activity sheets for teachers to copy, a glossary, a resource list, a 4-color poster, and a badger mask. The final printed version of the guide is scheduled for Spring, 1993.

METHODS AND RESULTS

January - March:

The timeline, outline and format for the guide were finalized, and rough-draft versions of the Introductory Materials section and several activities were developed. The mask designer was contacted about developing designs for a mask. A preliminary selection of Shattil/Rozinski photographs for the guide and poster was made. A script for the poster was started. The author worked with Graphics to develop a timeline for illustrating, designing, editing, field testing, and printing the guide. A list of teachers for a teacher focus group was develped.

The following is an outline of the guide, as well as a description of the activities and other materials that were developed in this quarter:

Introductory Materials. Materials developed include a description of the Arsenal and its importance as a wildlife sanctuary, as well as information for teachers on how to use the guide.

Unit I: Wildlife at the Arsenal. Materials developed included the overview and the following activities: "A Prairie Dog Tale" (later renamed "The Shrinking Prairie" and "Who Lives Here?"

Unit II: Yesterday and Today.

Unit III: Hazardous Wate and Wildlife. Materials developed included the Overview and the activity "There Is No Away."

Unit IV: Careers in Natural Resources.

Unit V: Looking Ahead

Related Education Sources. A partial list was developed.

April - June

Revisions and refinements were continued on materials previously developed for the guide, including introductory materials, activities, glossary, related education sources, and poster. New activities and materials were also developed. Work was continued with Graphics, the mask designer, the photographer, and the teacher focus group list. Environmental education classes for elementary students were observed at the Arsenal. The author also organized and staffed an exhibit on birds of the Arsenal at the Arsenal 's May 9 open house.

The following is the outline for the guide, including descriptions of new activities and other materials developed.

Introductory Materials include: A) Information about the importance of the Arsenal as an EPA Superfund cleanup site and its role as a model for similar sites in country. B) The significance of the Arsenal as a refuge for a large number of wildlife species.

Unit I: Wildlife at the Arsenal. New materials developed include the feature "Threatened and Endangered Species at the Arsenal" (This feature has been replaced with a feature on bald eagles.)

Unit II: Yesterday and Today. New materials developed included the overview as well as the following activities: "Habitat Changes at the Arsenal" and the "History of the Arsenal Card Game." (This activity has been replaced with "The Refuge Game,." a board game.)

Unit III: Hazardous Waste and Wildlife. New materials developed include the following activities: "Deadly Links at the Arsenal" and "Going Down." (This activity has been replaced with an activity about groundwater pollution called "There Is No Away.")

Unit IV: Careers in Natural Resources. New materials developed include the following activites: "Investigating Some Animals and Their Environment" and "Graphing Species". (These activities have been replaced by "The Tagging Game" and "The Deer Management Problem".)

Unit V: Looking Ahead. New materials developed include the Overview and the following activity: "The Conservation Conversation Show" (This activity has been replaced by "Land Use Planning".)

July - September

Materials previously developed for the guide were revised and refined. New activities and materials were also developed. Work was continued with Graphics to develop illustrations and design of the guide. Work was continued with the mask designer to create a badger mask. The author also consulted with U.S.F.W.S., Colorado Wildlife Society, and other agencies to develop a teacher focus group. Meetings were held with photographers to continue selecting photos for the guide.

The following is a summary of activities and other materials developed during this quarter:

Introductory Materials: Revisions and refinements continued on previously developed materials, i.e. the importance of the Arsenal as an EPA Superfund site and its role as a model for similar sites in the nation; the significance of the Arsenal as a haven in an urban area for a diversity of species.

Unit I: Wildlife At The Arsenal. Materials developed and revised include the following activities: "Habitats at the Arsenal" (later changed to "Who Lives Here?), the "Food Web Game" (later eliminated), "Build a Prairie Dog Town" (later changed to "Dig That Prairie Dog Town"), and "Fun Facts About Badgers" (later changed to "Facing a Badger"). A special feature, "Bald Eagles at the Arsenal," was also developed.

Unit II: Wildlife at the Arsenal. Materials developed and revised include the Overview and the following activities: The Shrinking Prairie", "Habitat Changes at the Arsenal," and "The Refuge Game."

Unit III: Hazardous Waste and Wildlife. Materials developed and revised include the following activities: "There Is No Away," "Deadly Links on the Prairie," and "What Are the Alternatives?" A special feature, "What is a Superfund Site?", was also developed.
Unit IV: Careers in Natural Resources. Materials developed and revised include the Overview, including list of colleges and universities in Colorado with programs in natural resources. Activities developed: "The Tagging Game," "The Deer Management Problem," and "Investigating Some Animals and Their Environment" (later eliminated).

Unit V: Looking Ahead. Materials developed include the Overview and the following activities: "Land-use Planning," "Planning a Wildlife Refuge At Your School," and "Legislating for Wildlife." Two special features were also developed: "Timeline of Legislation for the RMA Refuge" and "Profile of Martin Luther King School 's Nature Area."

October - December

Materials previously developed for the guide were revised nd refined. The first draft of the manuscript was finalized and submitted to teachers, curators, and other experts for review. The author worked extensively with the museum Graphics staff to develop game board layout, prairie dog town model, and other graphics and illustrations for the guide. Meetings were held with U.S.F.W.S. to solve problem of copyright and printing rights, as well as problem of integrating on-site materials with pre- and post-visit materials.

The author worked closely with the editing staff of the museum to review and revise the manuscript according to peer review suggestions. A second draft of the manuscript was completed and given to Graphics for layout and illustrating. Photos, graphs, charts, maps, and other graphics were gathered by the author, who continued to work closely with the Graphics and Editing staff.

PLANS FOR 1993

The illustrated third draft of the guide will be field tested by teachers and their students in February 1993, and then revised according to the teachers' and other reviewers' suggestions. The final version of the guide will be printed in Spring 1993 and distributed by U.S.F.W.S. 1993.

QUARTERLY REPORT

January - March, 1992

Mammals 1, 4400 HUNT 0700

Work Plan 2, Job 16:

D. L. Baker, Co-Investigator
T. M. Nett, Co-Investigator
M. M. Miller, Co-Investigator

Regulation of Deer Population Growth by Fertility Control

We conducted experiments to measure pituitary response of hypothalamic-gonadotropin releasing hormone (GnRH) in mule deer during November 9 - December 11, 1992. The objective of this experiment was to determine the most effective dose of GnRH analog necessary to produce maximal release of luteinizing hormone (LH). This information is fundamental to determining the most effective dose of GnRH-toxin conjugate in mule deer. Because of the limitations on production, it is imperative to determine the minimum dose that will provide consistent results. We conducted trials during the peak of the breeding season to insure that the pituitary was at its most active state when stimulated by analogs of GnRH. Here, we report our preliminary findings. Statistical analysis of these data are currently in progress.

We administered 5 doses of GnRH analog to each of 5 deer (3 adult females, 2 male castrates) in a randomized complete block design with repeated measures structure (Table 1). Each deer was anesthetized with 60-70mg of xylazine hydrochloride (100mg/cc) and fitted with an indwelling jugular catheter. Concentrations of LH in serum were measured at 0 (immediately prior to treatment), 30, 60, 90, 120, 180, 240, 300, and 360 minutes post-treatment. Blood was allowed to clot at room temperature prior to centrifugation. Serum was harvested the next day and frozen at -20C. Serum LH and was determined using radioimmunoassay. The LH response to varying doses of GnRH analog was assessed by (1) determining the maximal concentration of LH released (peak of LH curve), (2) time interval from injection of GnRH bolus to peak LH concentration, and (3) the total amount of LH released (estimated by calculating the area under the LH curve).

Treatment of mule deer with GnRH agonist induced release of LH from the anterior pituitary. The pattern of LH release over time differed considerably between females and male castrates and among individuals of both sexes (Figs.1-10). Male castrates generally exhibited higher baseline concentrations of LH (Table 2) and patterns of release that were of longer duration than females. Regardless of sex, LH began to increase 30 minutes after administration of GnRH with the maximum concentration of LH occurring between 180 and 237 minutes post-injection (Table 3). Peak concentrations of LH tended to be higher for females than males for all treatments (Table 2). Averaged across all female deer, peak concentrations of LH occured at a dose of 1 microgram/50kgBW and declined thereafter with increasing doses of GnRH agonist (Table 2). While considerable variation in peak LH concentration exists among individual females at this dose, all showed relatively similar trends in response to increasing levels of GnRH agonist. Calculation of the total amount of LH released (area under the curve) for these treatments is in progress and should provide additional information on the most effective dose of GnRH for mule deer.

Table 1. Experimental design to determine dose requirement of GnRH analog for mule deer. All treatments within a column were administered on the same day. There was an 8 day interval between treatments within a row.

TRIAL DATE	NOV 9	NOV 17	NOV 25	DEC 3	DEC 11
Deer No.	DOSE (micrograms/50kgBW)				
S-90	0.0	0.3	1.0	3.0	10.0
R-86	0.3	1.0	3.0	10.0	0.0
Q-86	1.0	3.0	10.0	0.0	0.3
V-86	3.0	10.0	0.0	0.3	1.0
Z-89	10.0	0.0	0.3	1.0	3.0

Table 2. Peak concentrations (ng/ml) of LH in mule deer challenged with varying doses (micrograms/50kgBW) of GnRH agonist.

	Females		Male Castrates		All Deer	
Dose	Mean	S.E.	Mean	S.E.	Mean	S.E.
0.0[a]	0.18	0.02	1.31	0.09	0.63	0.92
0.3	6.32	3.41	2.56	0.50	4.81	2.09
1.0	48.61	38.48	5.33	2.23	31.22	23.66
3.0	9.39	3.53	6.12	0.27	8.00	2.02
10.0	12.92	6.80	7.34	2.84	10.69	4.07

[a] Average baseline LH concentration was calculated for the control dose.

Table 3. Time (min) from injection of GnRH bolus to peak concentration (ng/ml) of LH in mule deer challenged with varying doses (micrograms/50kgBW) of GnRH agonist.

	Females		Male Castrates		All Deer	
Dose	Mean	S.E.	Mean	S.E.	Mean	S.E.
0.0	---	---	---	---	---	---
0.3	180	34.40	188	24.54	183	39.84
1.0	201	19.57	193	109.32	197	36.24
3.0	182	1.76	210	28.58	193	11.52
10.0	219	22.67	237	62.68	226	23.83

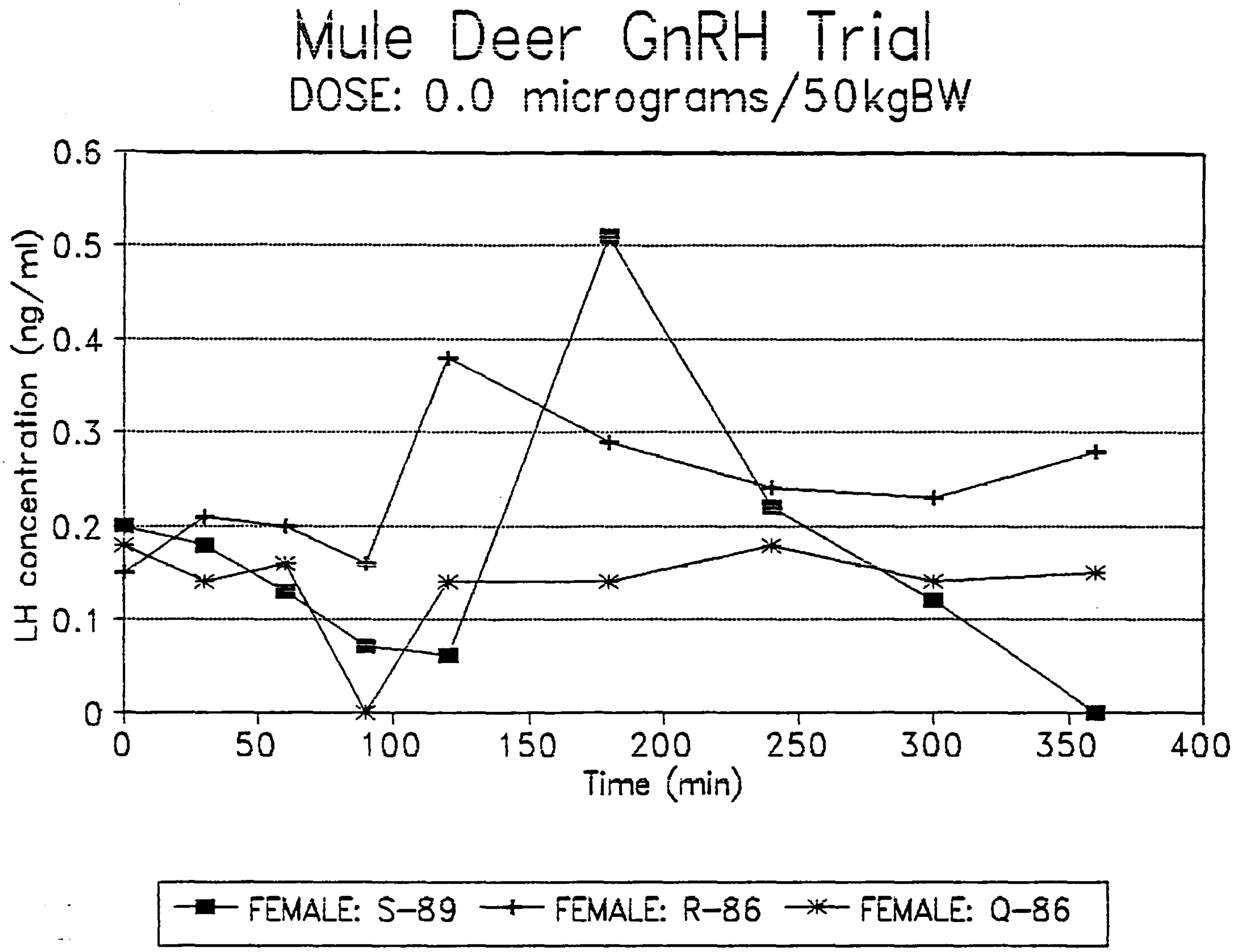


Figure 1. Baseline serum LH concentrations of 3 female mule deer given a dose of 0.0 micrograms/50kgBW (control) of GnRH analog.

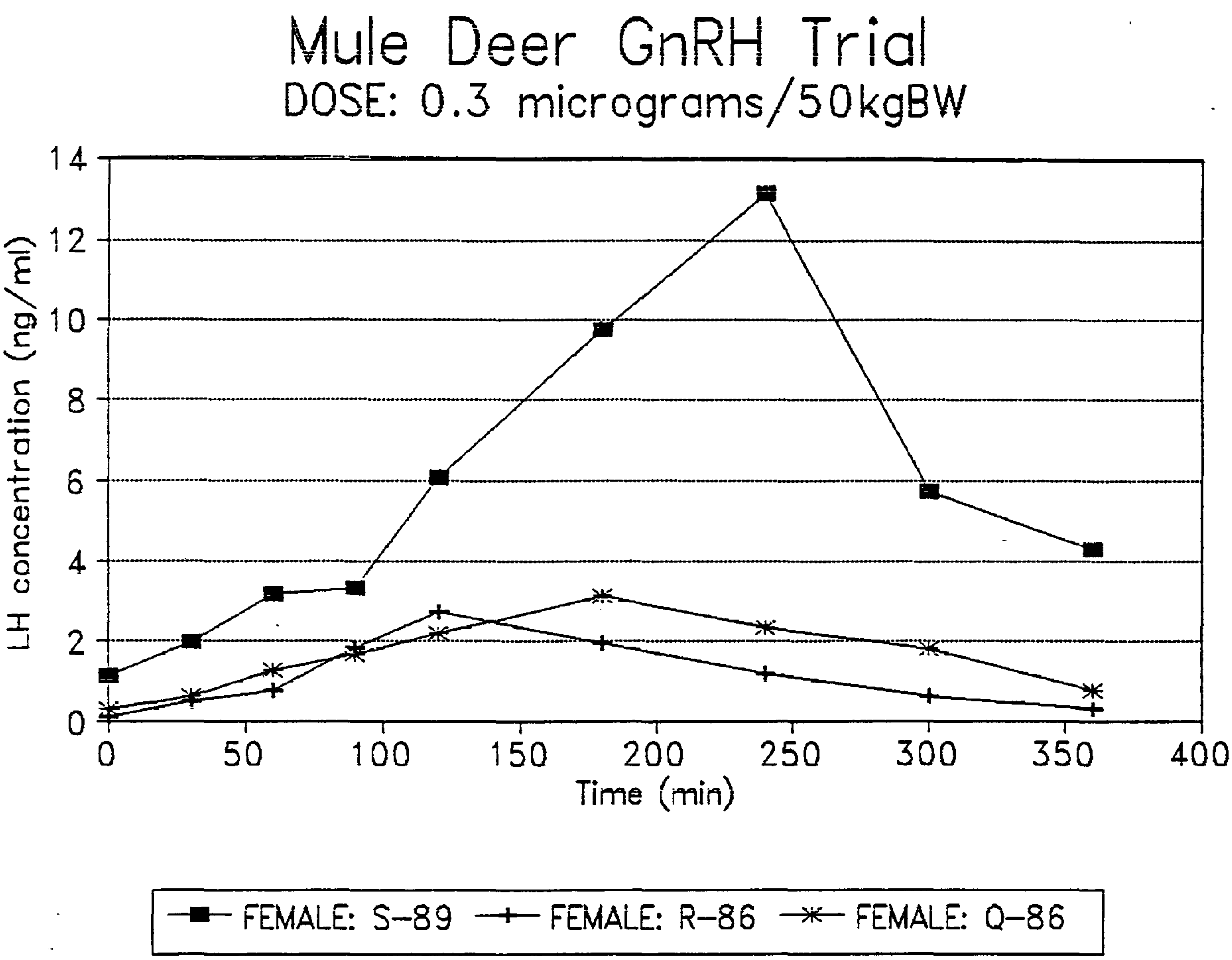


Figure 2. Serum LH concentrations of 3 female mule deer given a dose of 0.3 micrograms/50kgBW of GnRH analog.

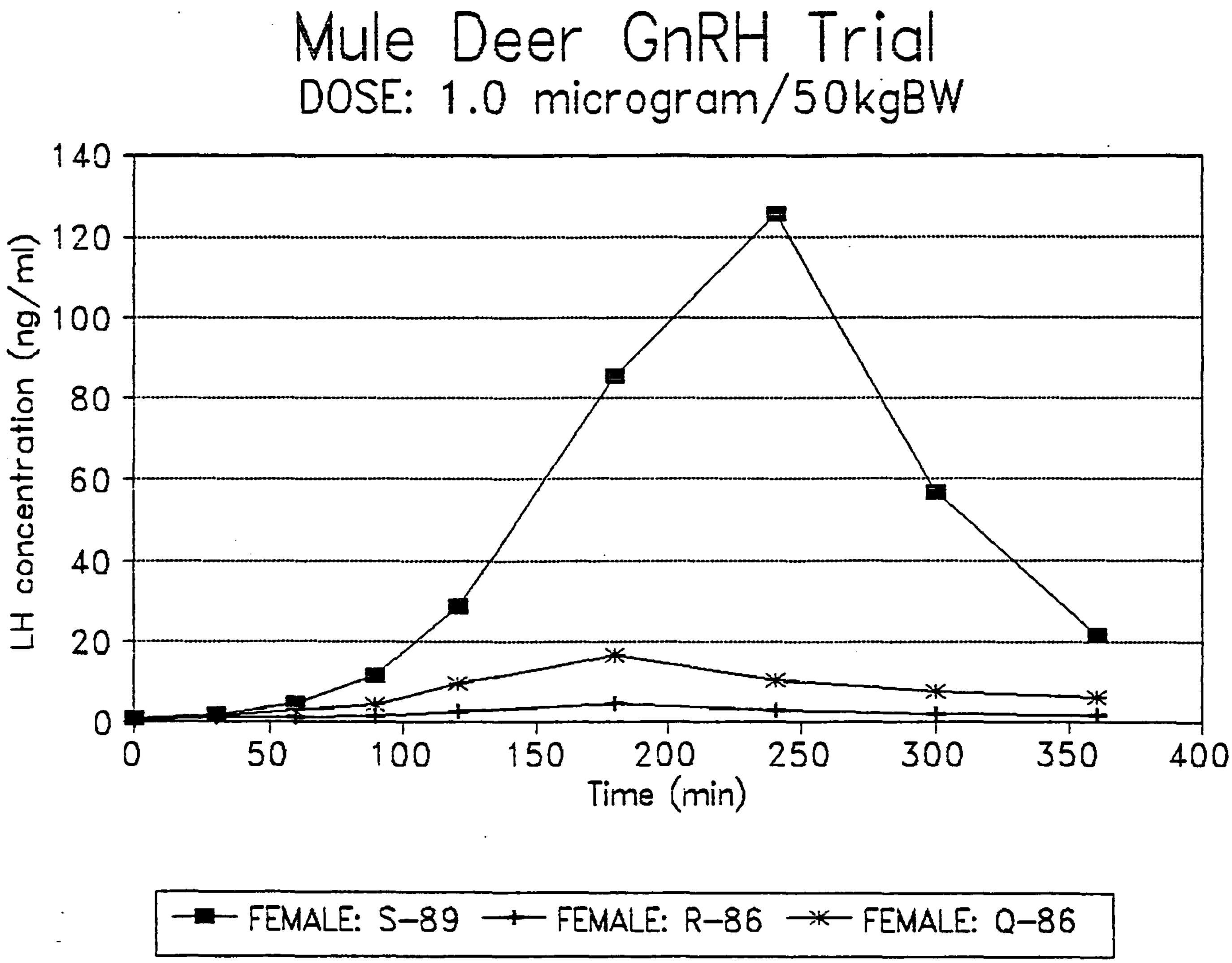


Figure 3. Serum LH concentrations of 3 female mule deer given a dose of 1.0 microgram/50kgBW of GnRH analog.

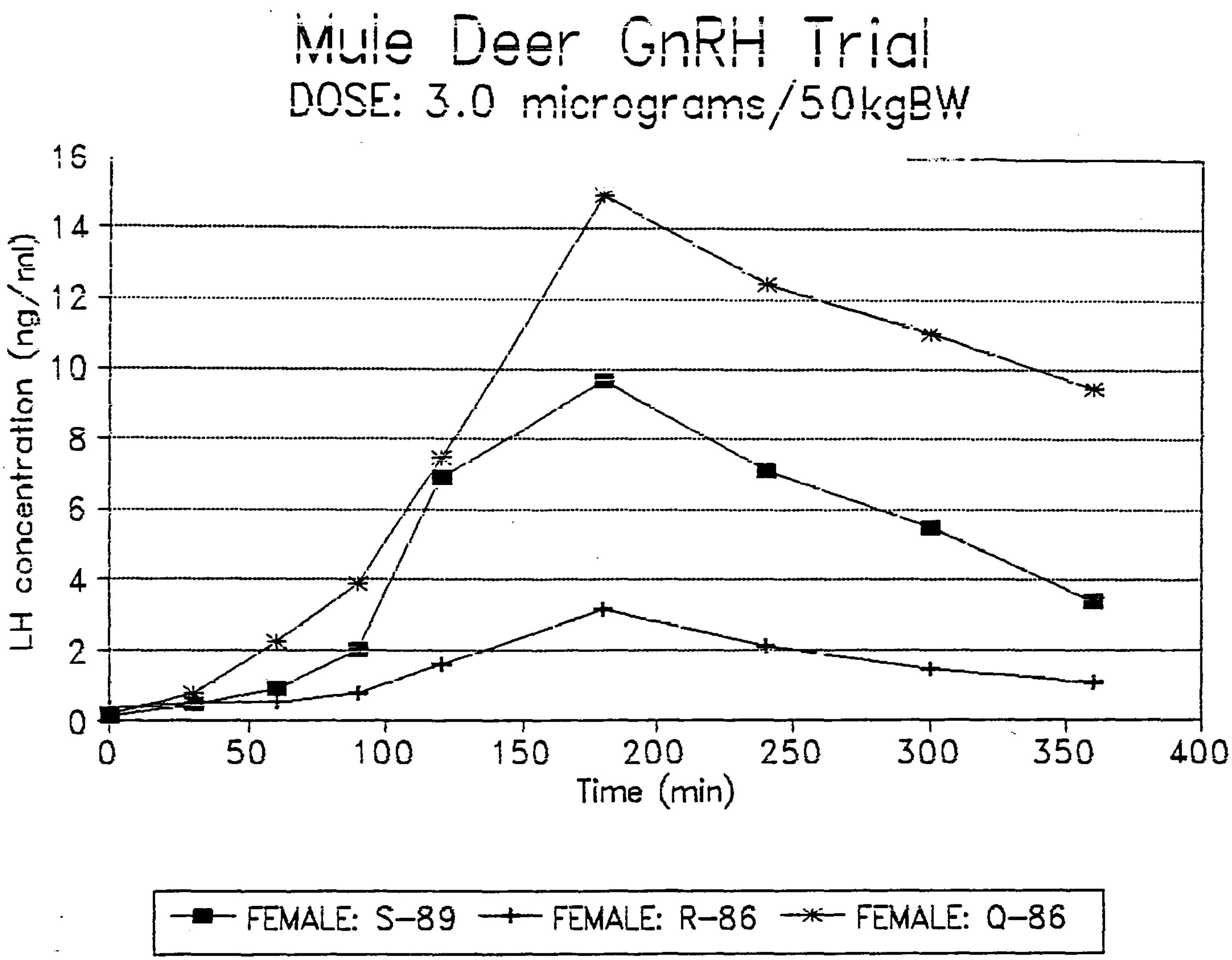


Figure 4. Serum LH concentrations of 3 female mule deer given a dose of 3.0 micrograms/50kgBW of GnRH analog.

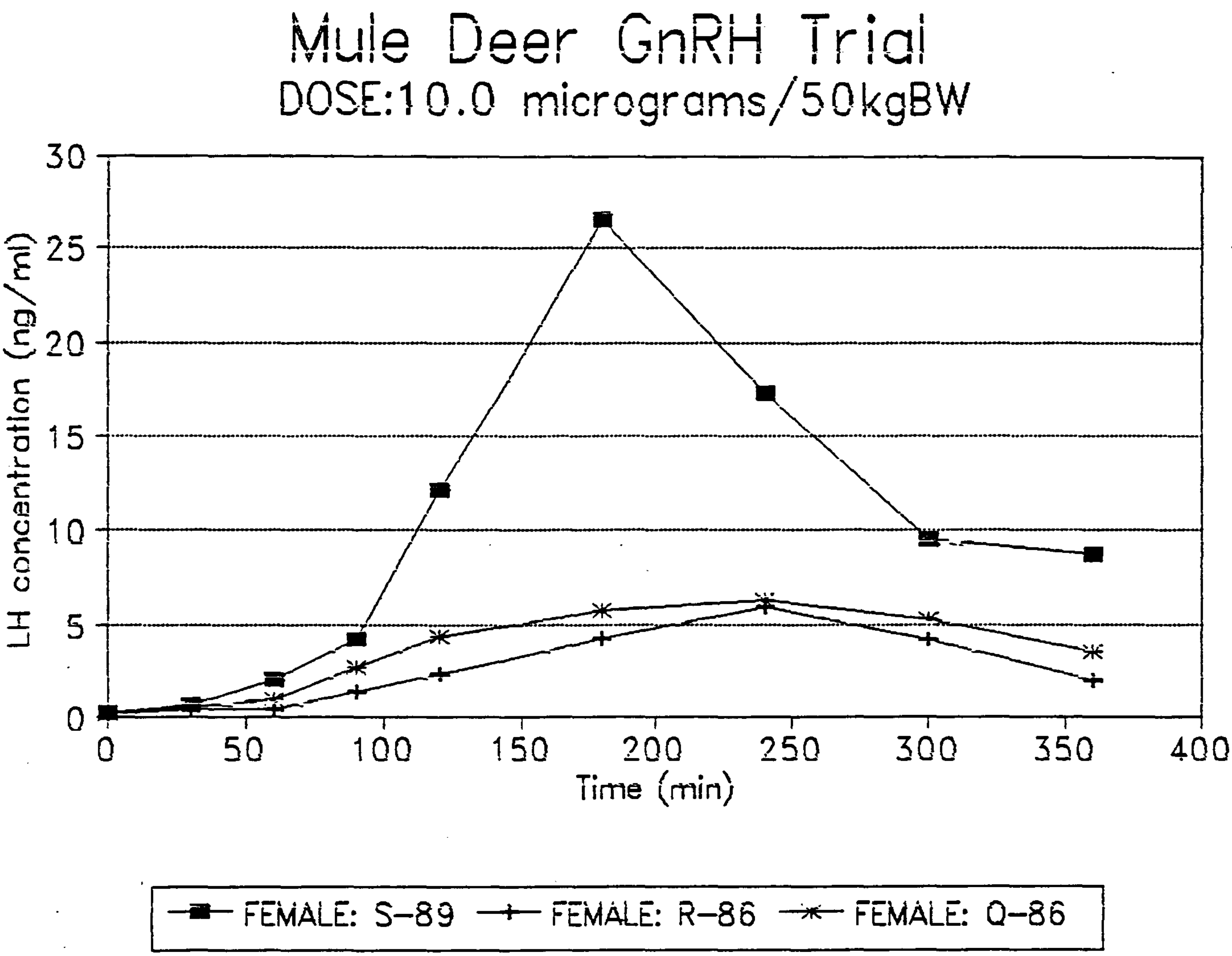


Figure 5. Serum LH concentrations of 3 female mule deer given a dose of 10.0 micrograms/50kgBW of GnRH analog.

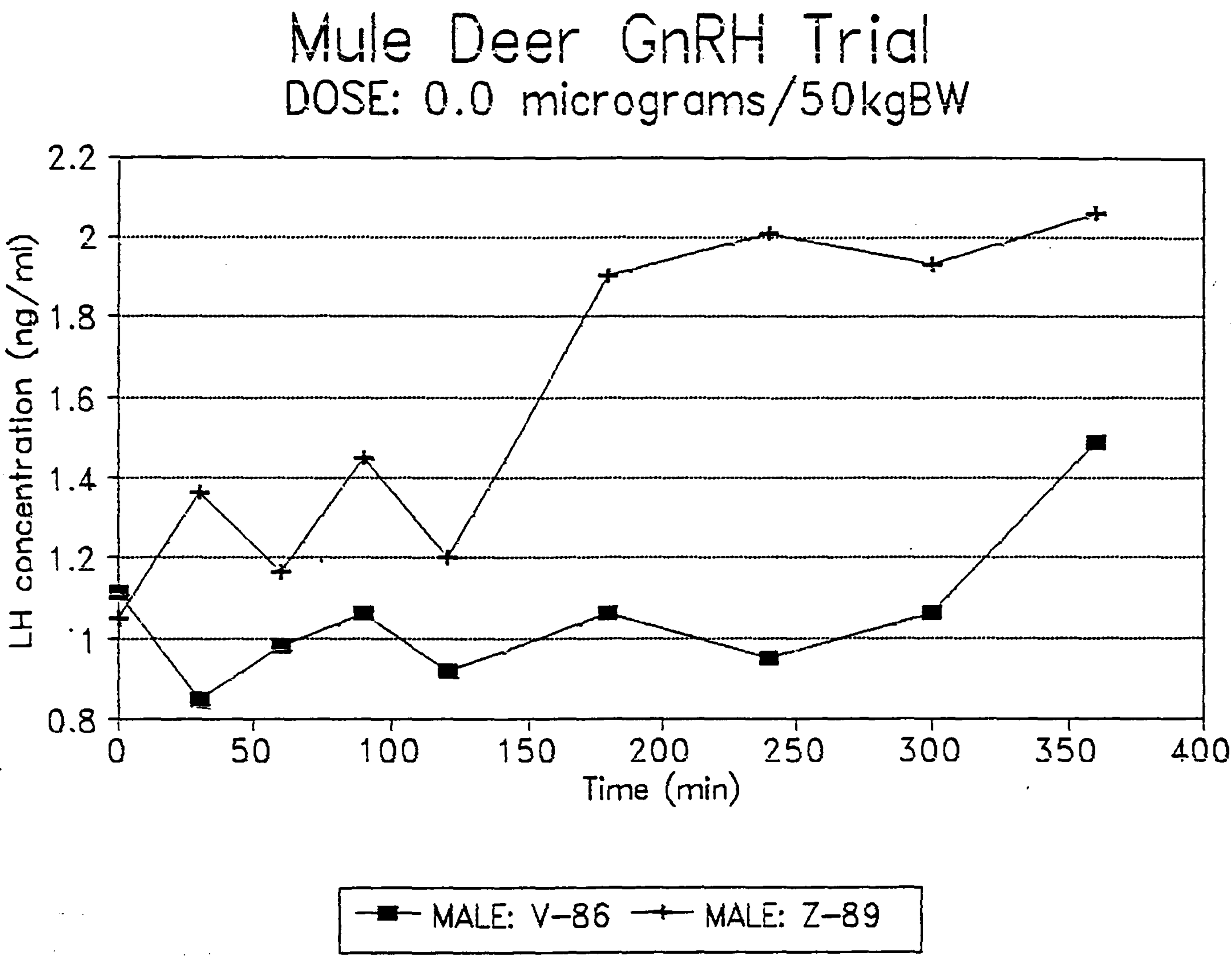


Figure 6. Baseline serum LH concentrations of 2 castrated mule deer given a dose of 0.0 micrograms/50kgBW (control) of GnRH analog.

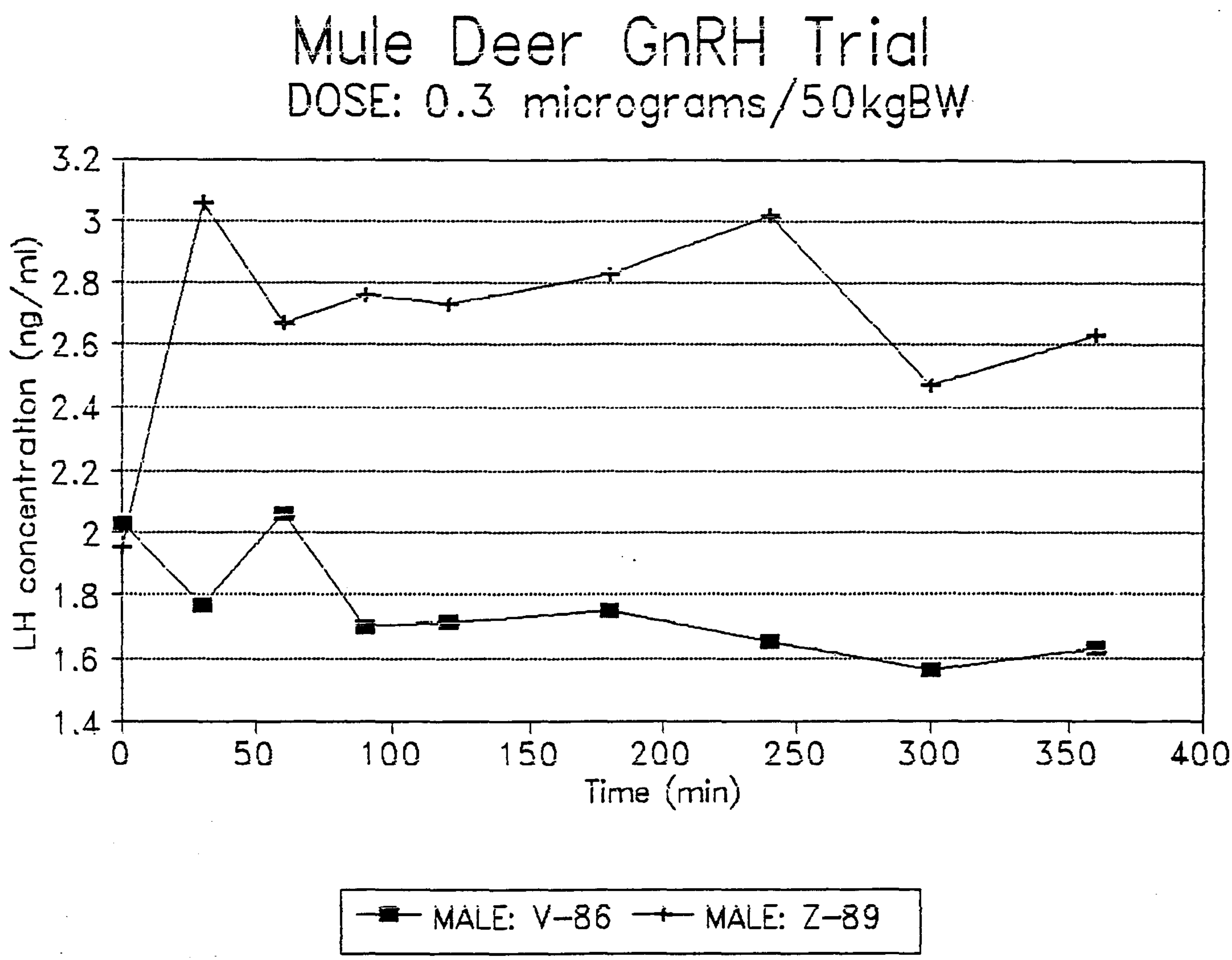


Figure 7. Serum LH concentrations of 2 castrated mule deer given a dose of 0.3 micrograms/50kgBW of GnRH analog.

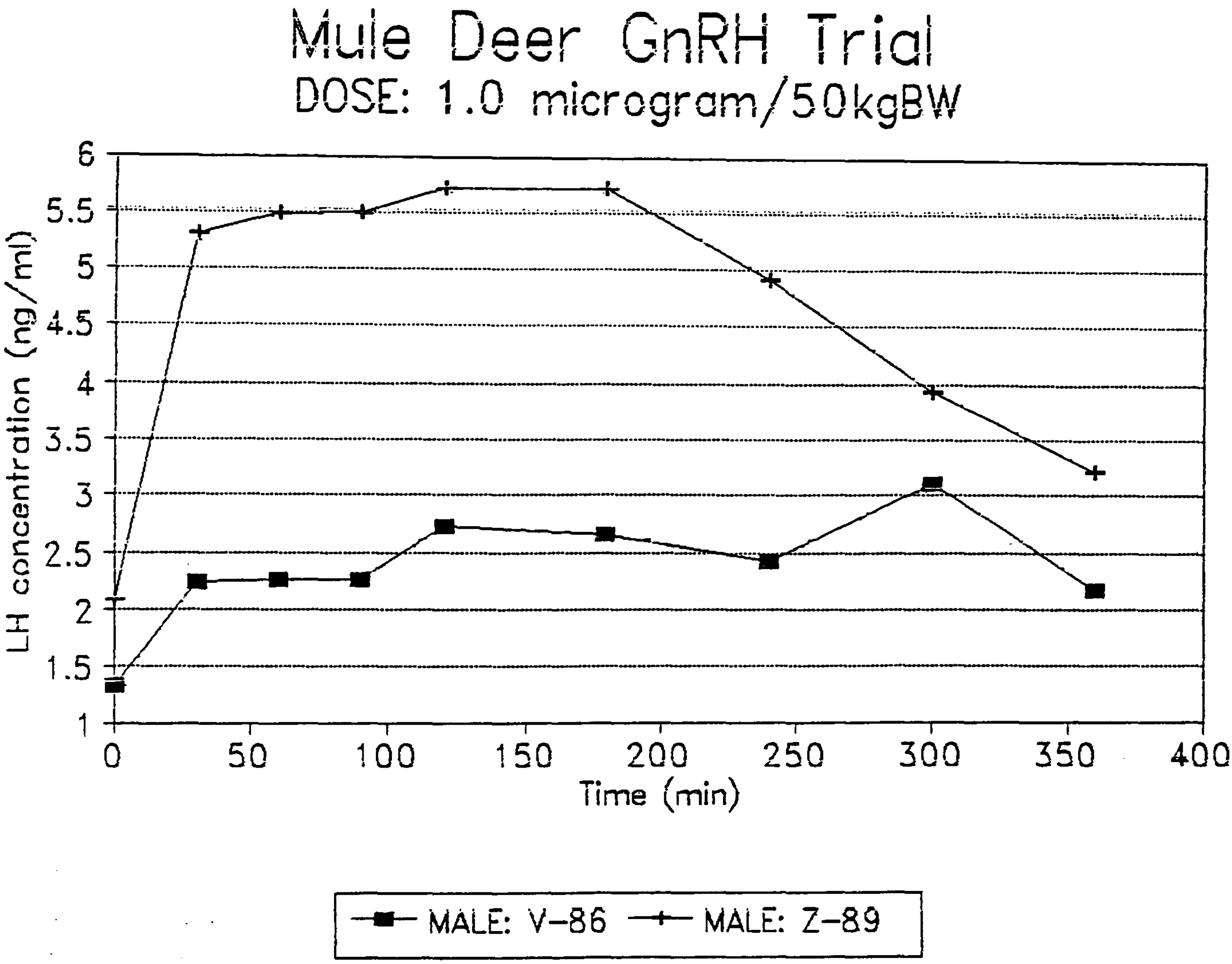


Figure 8. Serum LH concentrations of 2 castrated mule deer given a dose of 1.0 microgram/50kgBW of GnRH analog.

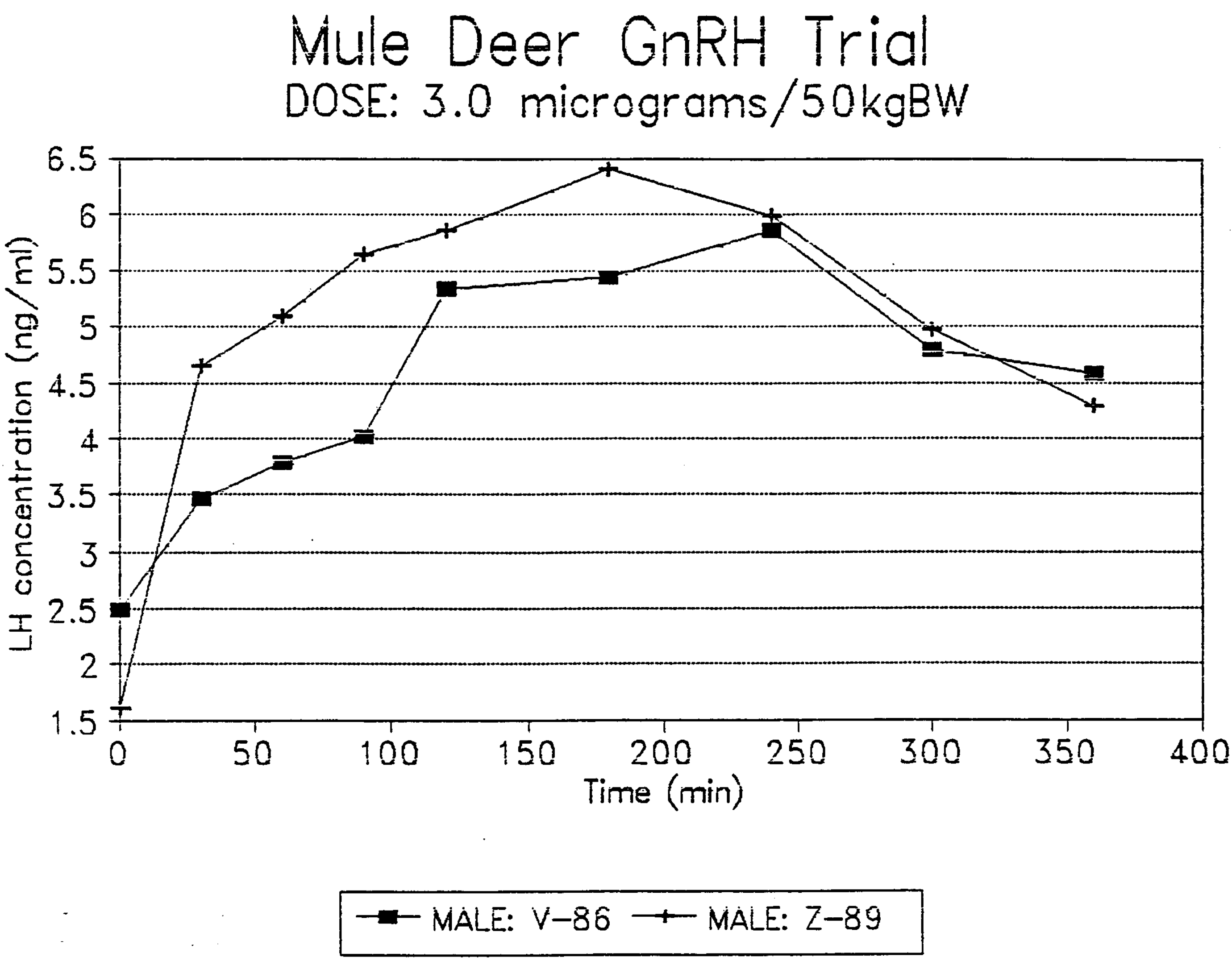


Figure 9. Serum LH concentrations of 2 castrated mule deer given a dose of 3.0 micrograms/50kgBW of GnRH analog.

REGULATION OF MULE DEER POPULATION GROWTH BY FERTILITY CONTROL: LABORATORY, FIELD, AND SIMULATION EXPERIMENTS

EXPERIMENT NO. 2 - INFLUENCE OF SEASON ON LUTEINIZING HORMONE RESPONSE IN MULE DEER CHALLENGED WITH GnRH ANALOG - PRELIMINARY REPORT

D.L. Baker, Co-Investigator
T.M. Nett, Co-Investigator
M.M. Miller, Co-Investigator

We conducted experiments to measure pituitary response to hypothalamic-gonadotropin releasing hormone (GnRH) analog in female mule deer during April 2 - May 12, 1992. The objective of this experiment was to evaluate the effect of season on luteinizing hormone (LH) response in female mule deer challenged with GnRH analog. The LH secreting cells in the pituitary are thought to be most responsive to GnRH stimulation when they are most active. For seasonally breeding mammals such as mule deer, this occurs during the peak of the breeding season, in late autumn. However, it may be necessary to deliver GnRH-toxin sterilization treatments to animals in the field when they can be trapped effectively, which is usually during late winter/early spring. For mule deer, this time period may correspond to the beginning of the anestrous phase of the reproductive cycle; a time when the pituitary may be the least responsive to GnRH stimulation.

The intent of this experiment was to determine if the pituitary is capable of responding to GnRH stimulation throughout the reproductive cycle. If release of LH is similar at both times of the year, then GnRH-toxin conjugate could be administered without regard to season of year and would allow treatment of deer when they would be most vulnerable to trapping.

We administered 5 doses of GnRH analog to each of 5 deer (3 pregnant adult females - Deer Nos. S-90, Q-86, R-86 and 2 non-pregnant yearling females - Deer Nos. A-91, R-91) in a randomized complete block design with repeated measures structure (the same experimental design used in Expt. 1). Each deer was anesthetized with 50-70mg of xylazine hydrochloride (100mg/cc) and fitted with an indwelling jugular catheter. Concentrations of LH in serum were measured at 0 (immediately prior to treatment), 30, 60, 90, 120, 150, 180, 240, 300, 360, and 420 minutes post-treatment. Blood was allowed to clot at room temperature prior to centrifugation. Serum was harvested the next day and frozen at -20C. Serum LH was determined using radioimmunoassay. The LH response to varying doses of GnRH was assessed by 1) estimating the maximum concentration of LH released (peak of LH curve), 2) interval (min) from injection of GnRH bolus to peak LH concentration, and 3) total amount of LH released. Prior to Trial No. 2, Deer Q-86 became ill and was removed from the experiment.

Treatment of female mule deer with GnRH agonist during anestrous induced release of LH. Patterns of LH release over time were similar for pregnant and non-pregnant deer (Figs.1-9). Non-pregnant deer, however, were consistently more responsive to GnRH stimulation than pregnant deer at the same dose of GnRH analog. Regardless of reproductive status, peak concentration of LH occurred at a dose of 1-3 micrograms/50kgW and did not change with increasing levels of GnRH analog (Fig.10). Levels of LH began to increase 30 minutes after administration of GnRH. Averaged across all female deer, maximum concentration of LH occurred about 213(SE=16) minutes post-injection; for pregnant deer 185 (SE=0.0) min; and for non-pregnant deer 271 (SE=41) minutes (Fig.11) Calculation of the total amount of LH released for each dose of GnRH analog is currently in progress and should provide additional information on the most effective dose of GnRH analog for female mule deer.

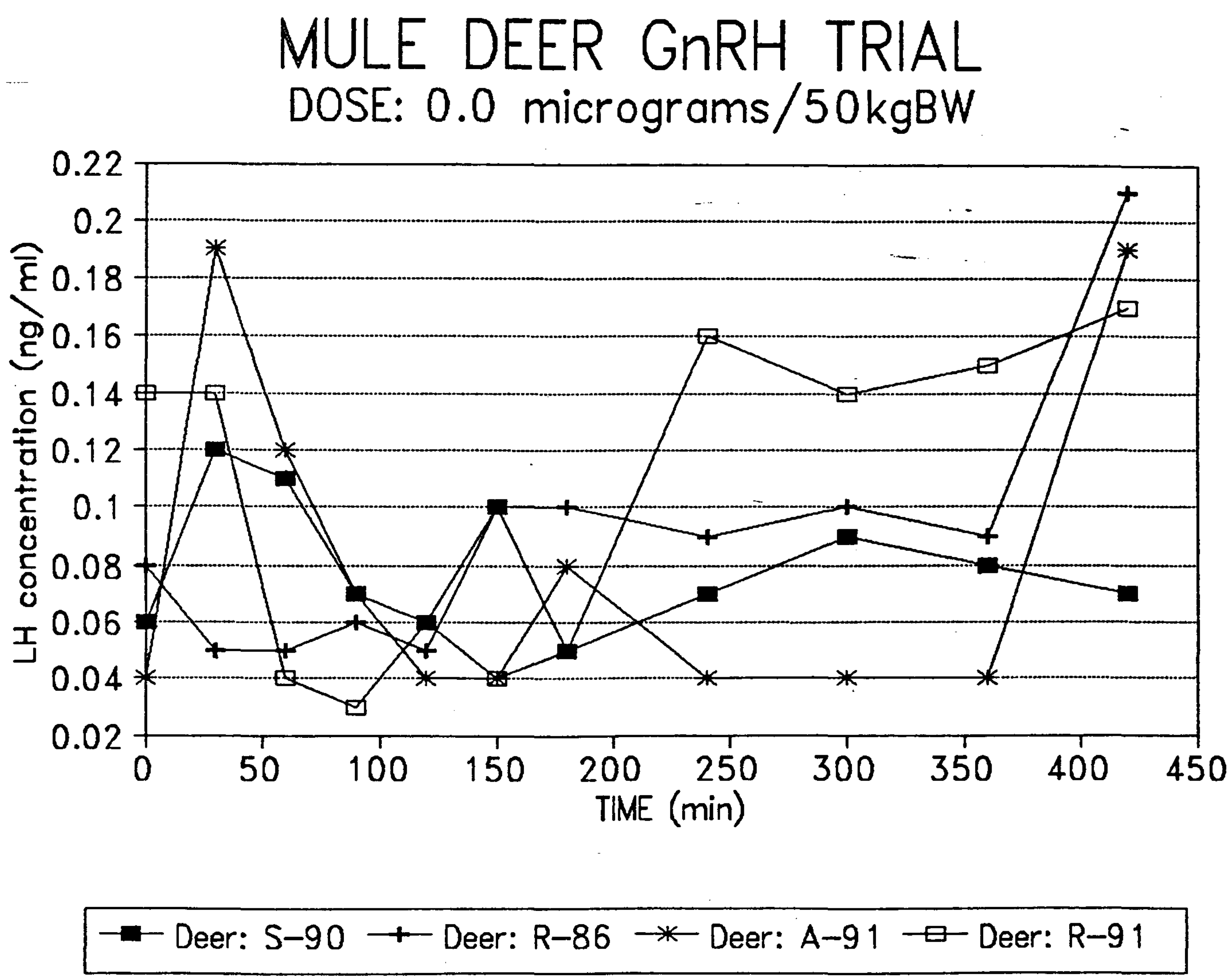


Figure 1. Baseline serum LH concentrations for 4 female mule deer given a dose of 0.0 micrograms/50kgBW (control) of GnRH analog during anestrus.

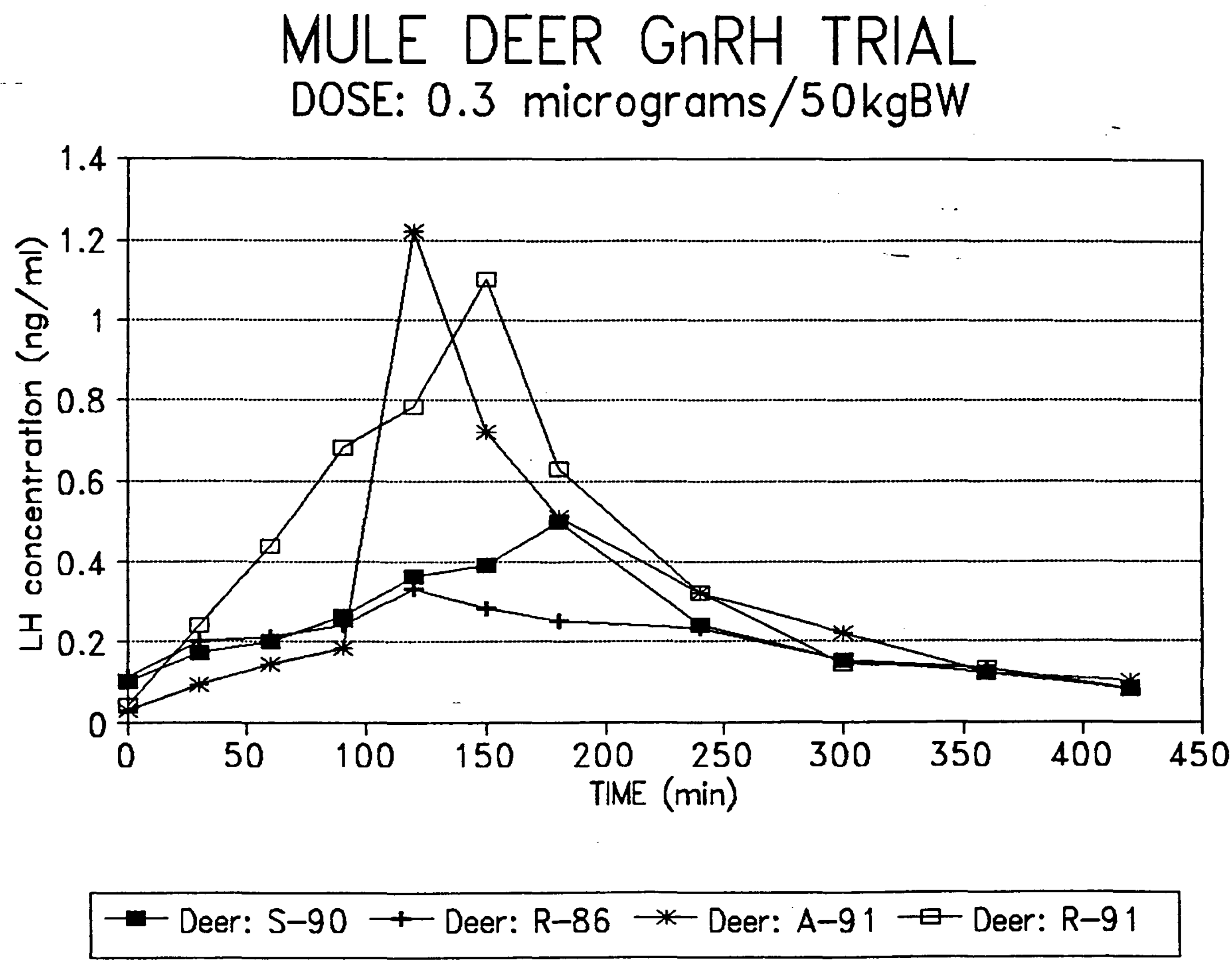


Figure 2. Serum LH concentrations for 4 female mule deer given a dose of 0.3 micrograms/50kgBW of GnRH analog during anestrus.

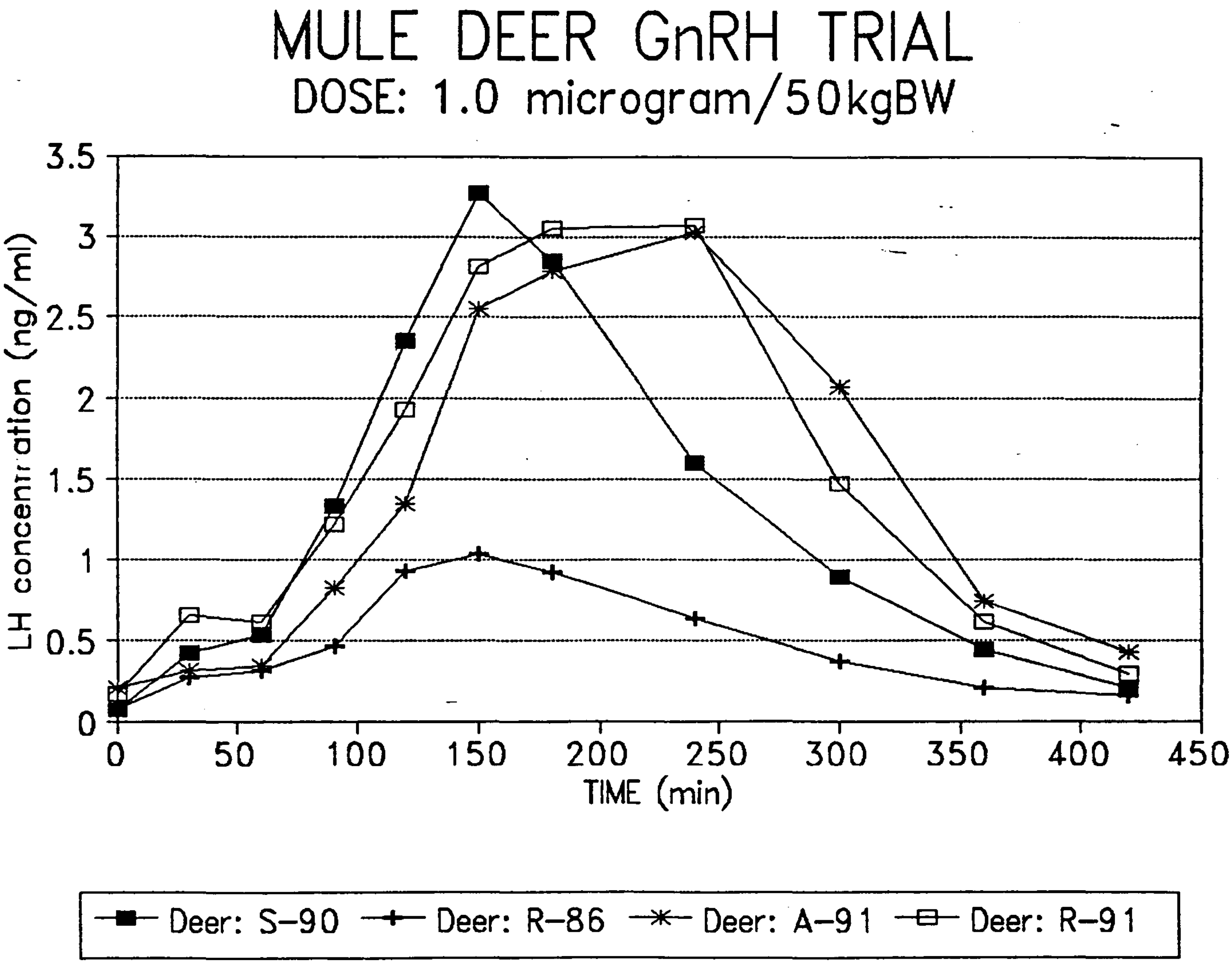


Figure 3. Serum LH concentrations for 4 female mule deer given a dose of 1.0 microgram/50kgBW of GnRH analog during anestrus.

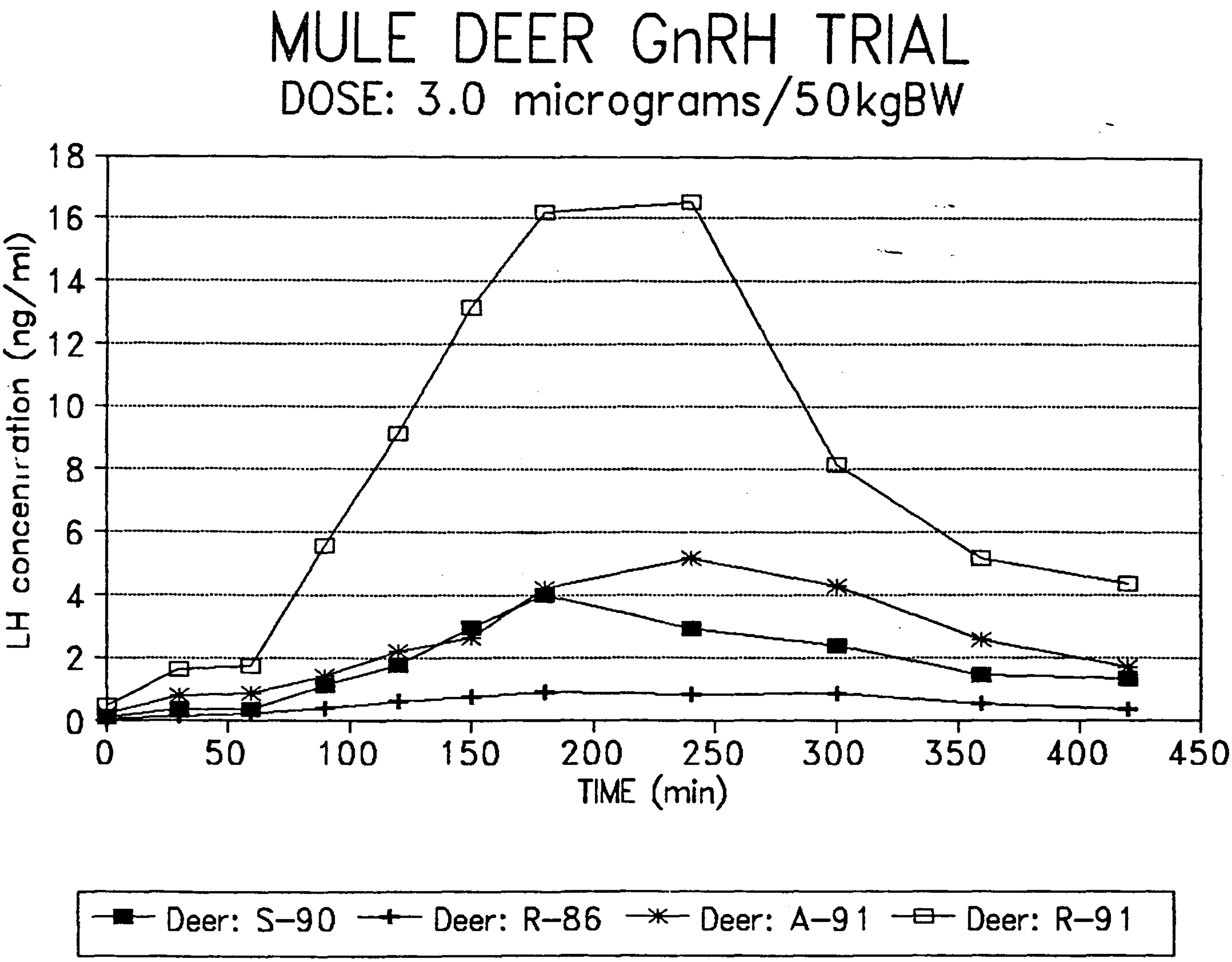


Figure 4. Serum LH concentrations for 4 female mule deer given a dose of 3.0 micrograms/50kgBW of GnRH analog during anestrus.

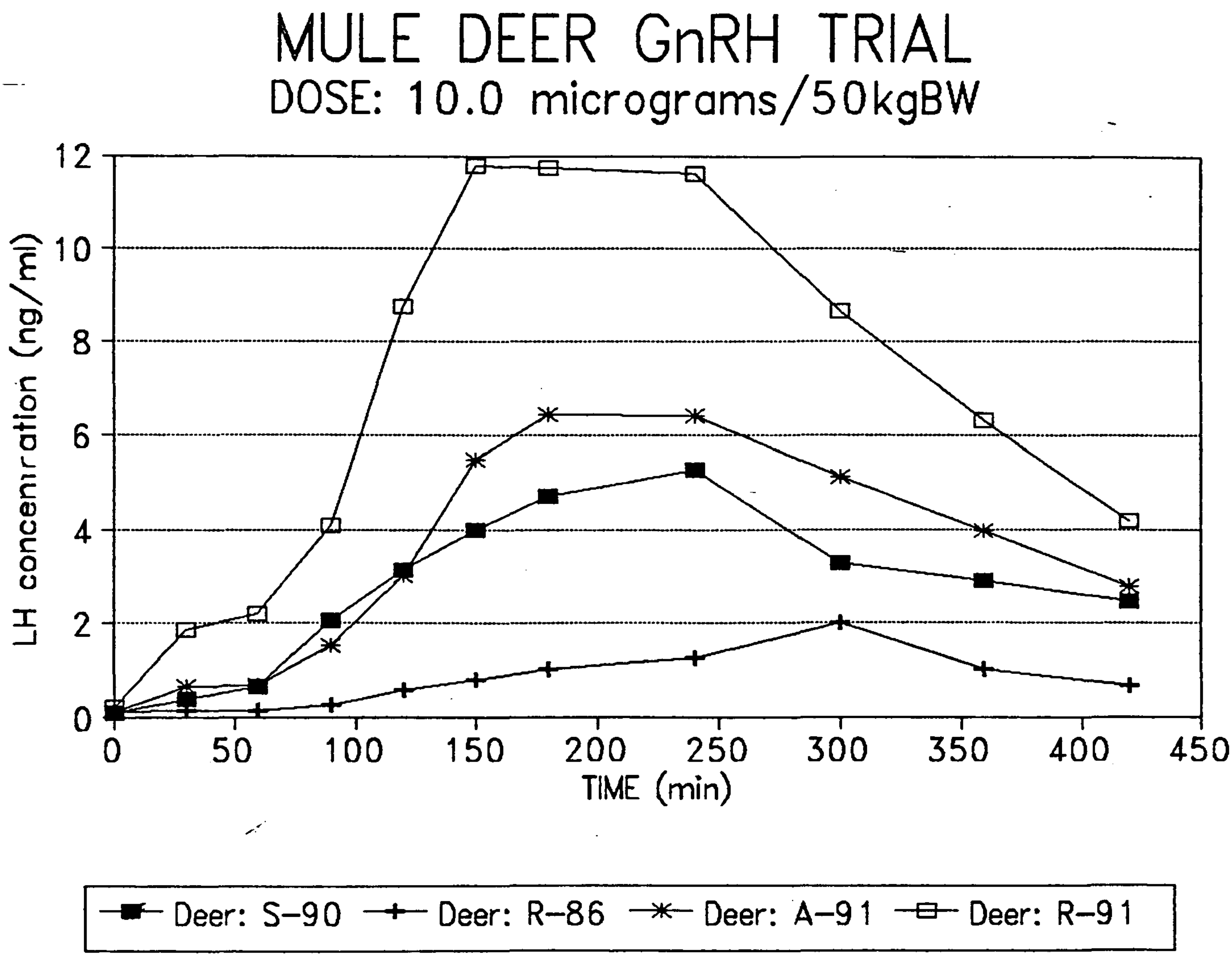


Figure 5. Serum LH concentrations for 4 female mule deer given a dose of 10.0 micrograms/50kgBW of GnRH analog during anestrus.

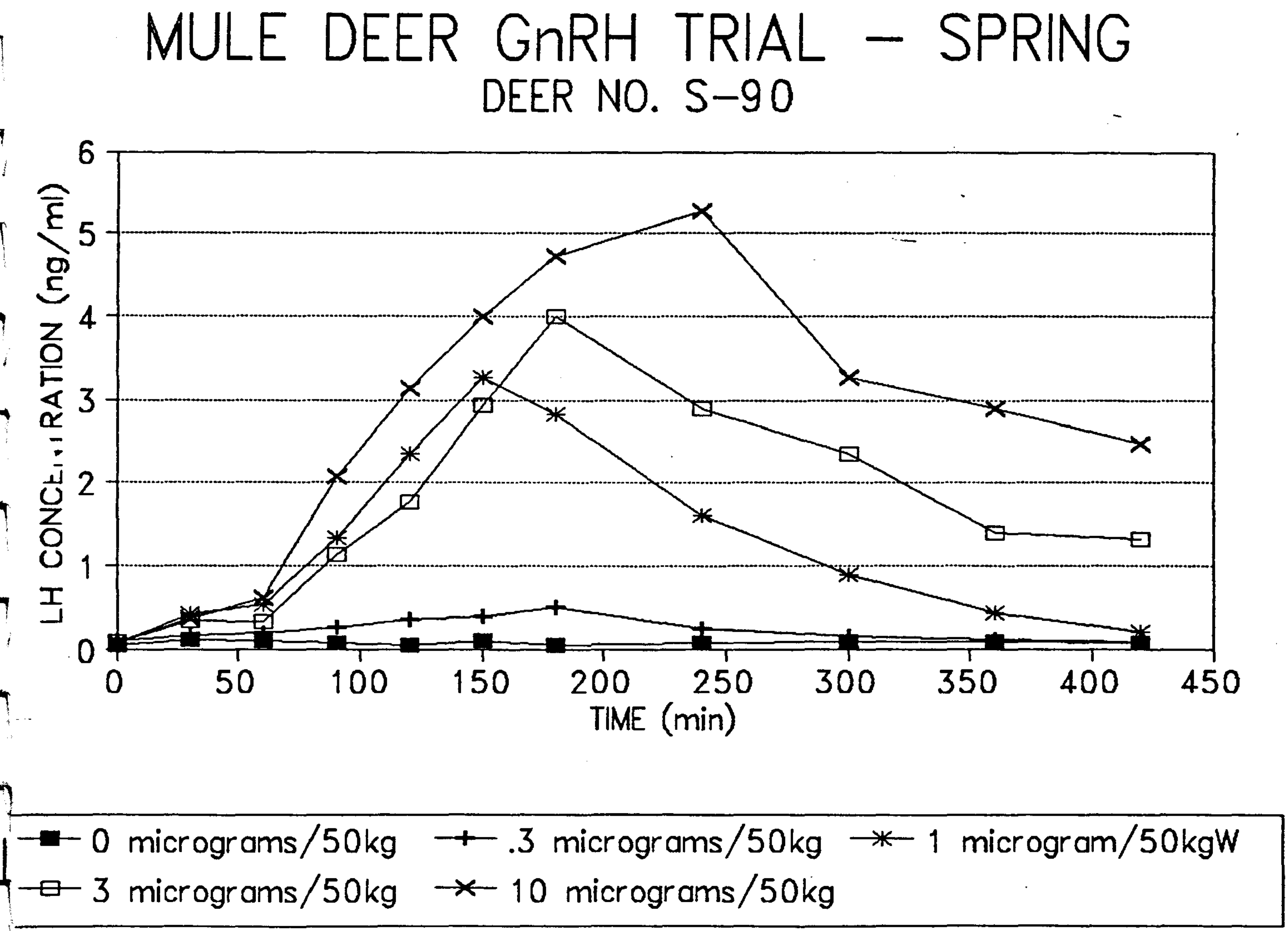


Figure 6. Serum luteinizing hormone (LH) concentrations (ng/ml) for pregnant female mule deer No. S-90 challenged with 5 levels of GnRH analog.

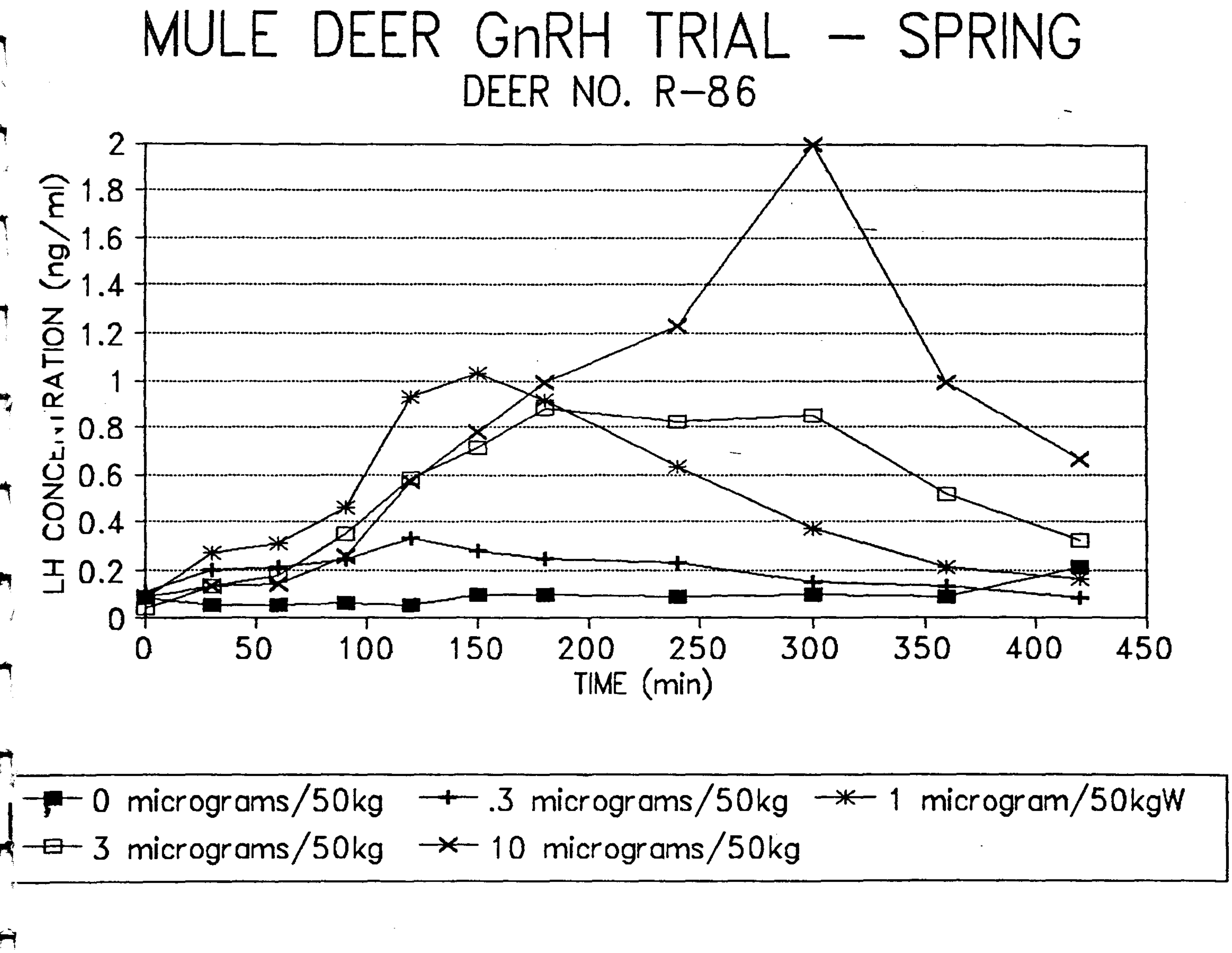


Figure 7. Serum luteinizing hormone (LH) concentrations (ng/ml) for pregnant female mule deer No. R-86 challenged with 5 levels of GnRH analog.

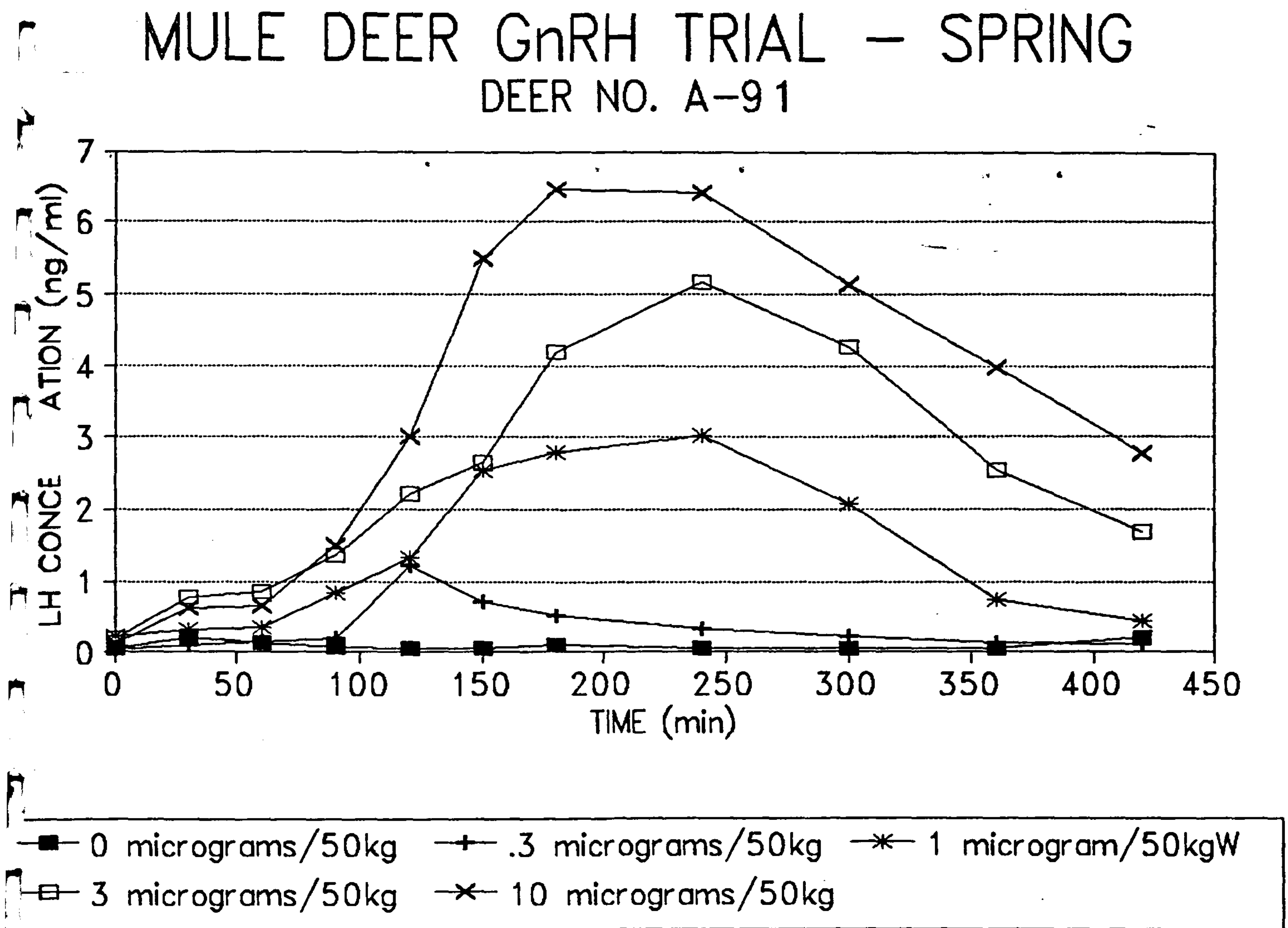


Figure 8. Serum luteinizing hormone (LH) concentrations (ng/ml) for non-pregnant female mule deer No. A-91 challenged with 5 levels of GnRH analog.

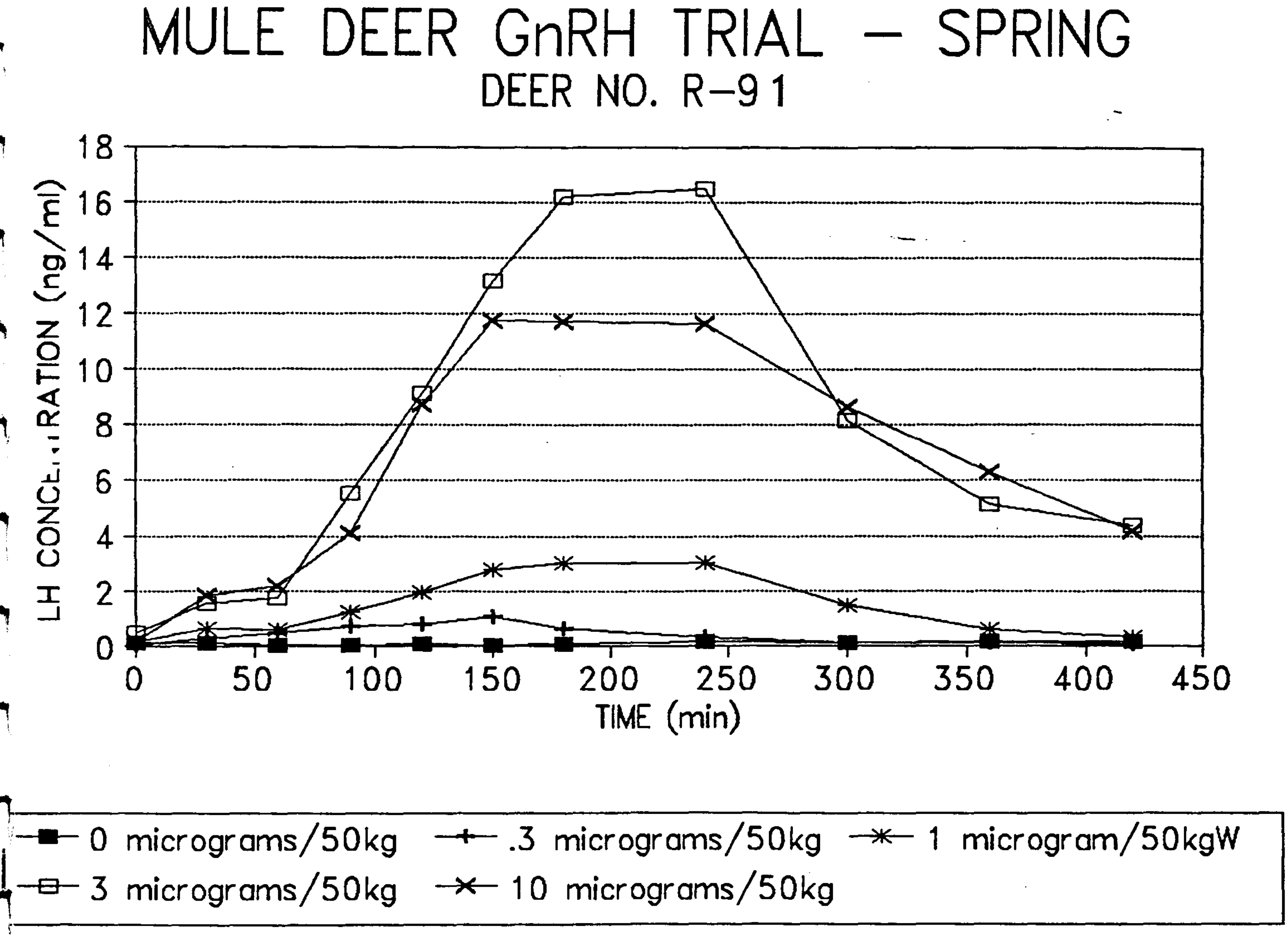


Figure 9. Serum luteinizing hormone (LH) concentrations (ng/ml) for non-pregnant female mule deer No. R-91 challenged with 5 levels of GnRH analog.

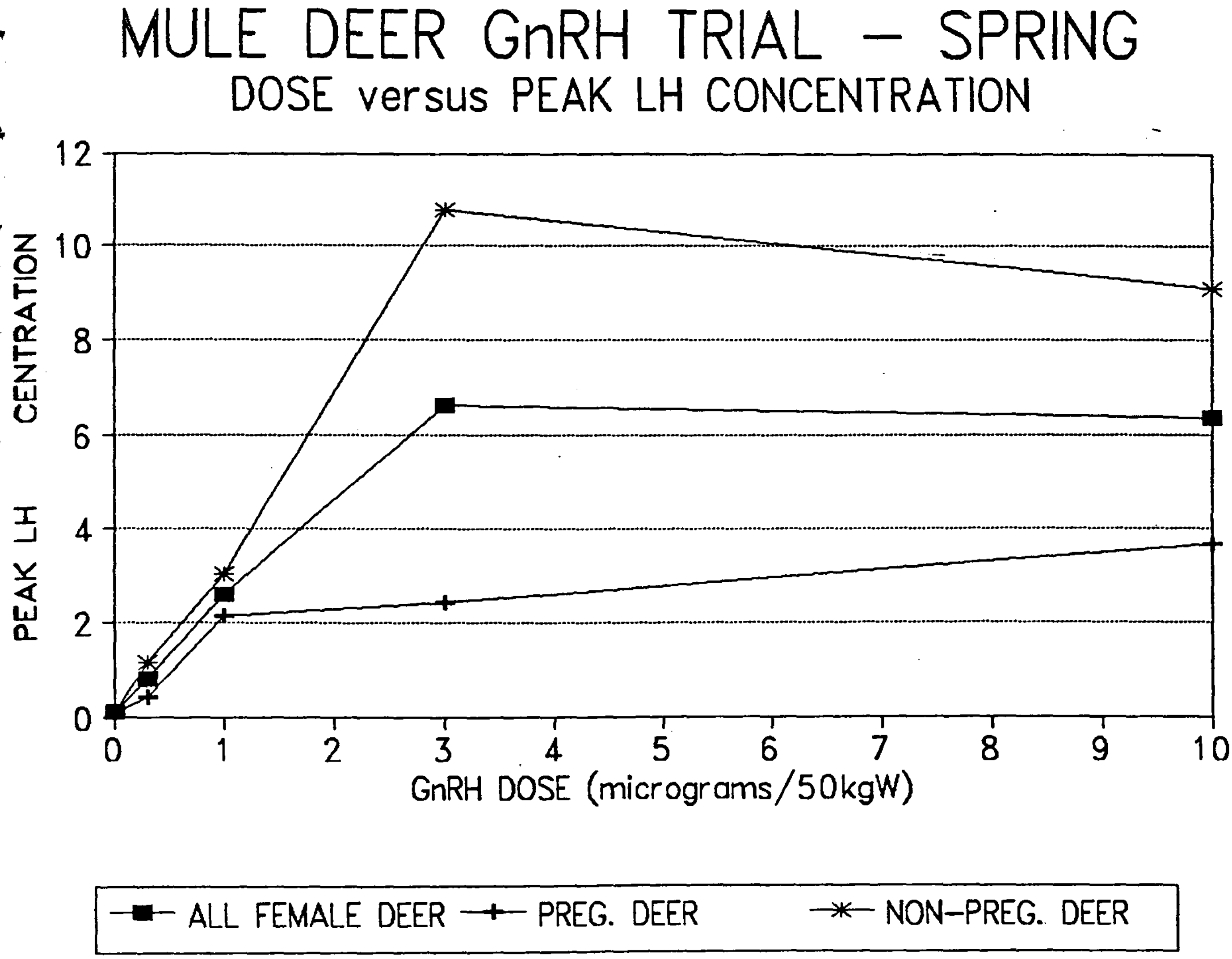


Figure 10. Average peak concentration (ng/ml) of luteinizing hormone (LH) for pregnant, non-pregnant, and all female deer challenged with 5 levels of GnRH analog.

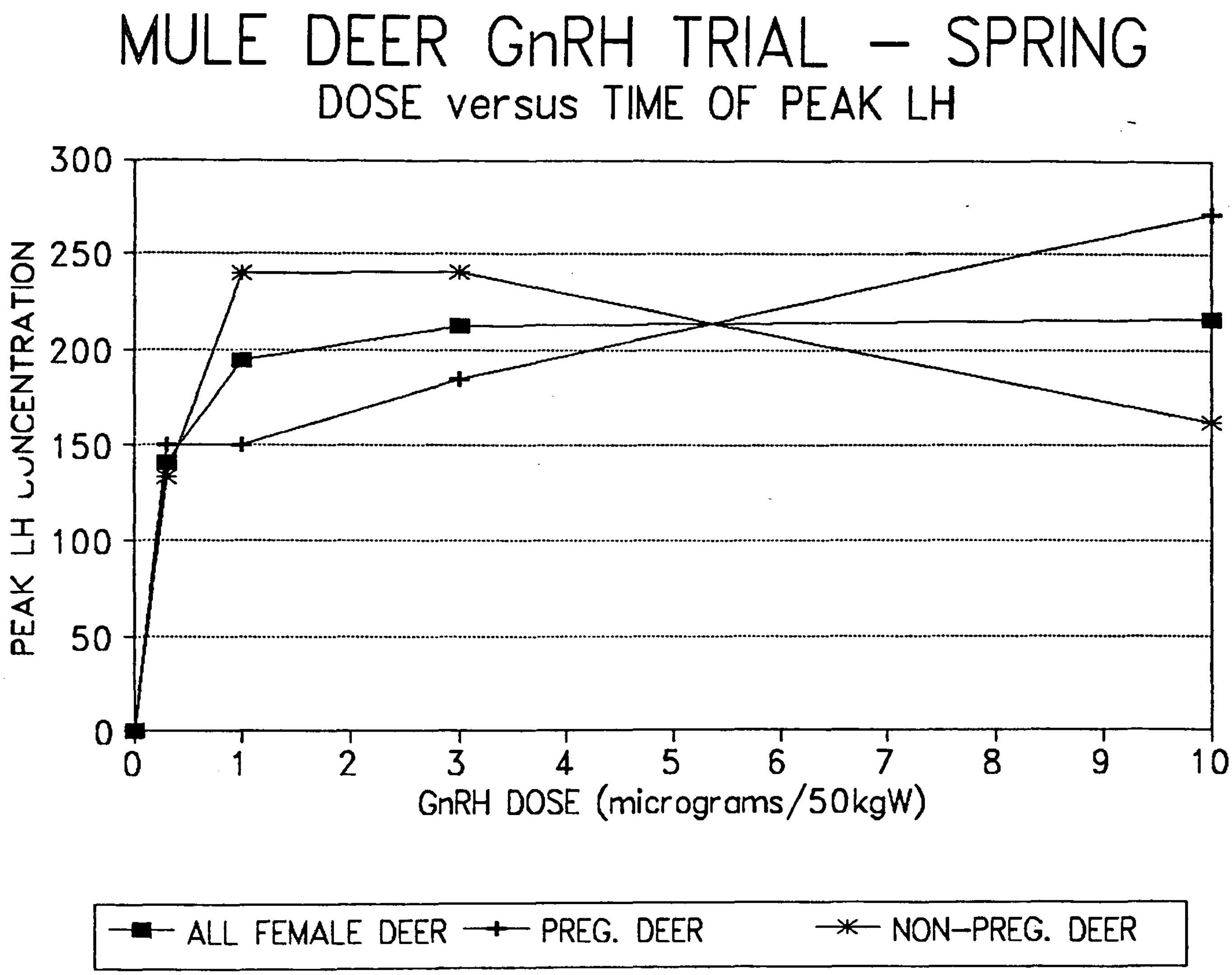


Figure 11. Average time (min) to peak concentration (ng/ml) of luteinizing hormone (LH) for pregnant, non-pregnant, and all female deer challenged with 5 levels of GnRH analog.

TITLE: Regulation of Mule Deer Population Growth by Fertility Control: Laboratory, Field, and Simulation Experiments

INVESTIGATORS: D. L. Baker, T. M. Nett, M. W. Miller, N. T. Hobbs, and R. B. Gill

INTRODUCTION

Controlling the growth of wildlife populations is fundamental to maintaining proper balance between animals and the habitats they use. Hunting has traditionally been used to maintain this balance, but there are an increasing number of circumstances where hunting wild animals to regulate their numbers is not feasible or where hunting is inconsistent with goals for land management especially when populations are managed primarily for non-consumptive uses.

The Rocky Mountain Arsenal offers rich opportunity for an urban population to view and enjoy Colorado's wildlife. However, the Arsenal presents unique problems as well as unique opportunities. For reasons of security, the perimeter of the area was fenced in 1988. While this fence does not impede the usual movements of birds and small mammals, it does create an unnatural barrier to movements by ungulates, particularly mule deer (Odocoileus hemionus). As a result, preventing those movements will almost certainly cause the deer population within the Arsenal boundaries to rise exponentially during the next decade. Experience with enclosed deer populations elsewhere has revealed that such increases will lead relentlessly to degradation of habitat, to widespread starvation, and eventually to catastrophic declines in animal numbers.

Experience has shown that the only way to prevent this trajectory is to control the abundance of enclosed deer populations. This is usually done by public hunting or by professional culling of animals. However, public hunting cannot be allowed on the Arsenal because of concerns for security. Moreover, although professional culling would eliminate excess animals, it would also reduce the value of the deer population as a watchable resource. In this situation, alternatives to hunting as a means of regulating ungulate numbers are needed.

Fertility control offers a viable alternative to hunting as a means of population control when hunting is infeasible. However, current fertility control technology does not provide a means of controlling ungulate numbers practically and economically. Here, we propose to develop a practical and economical method of fertility control in mammalian wildlife that overcomes many of the shortcomings of current technology, particularly problems of treatment duration and environmental safety. We propose to use conjugates of gonadotropin-releasing hormone (GnRH) and cellular toxins to selectively destroy gonadotropin-producing cells in the anterior pituitary gland, thereby preventing gamete production by the ovaries and testes.

The broad goals of our research are:

1) To develop a practical and acceptable method for controlling mule deer populations using GnRH-toxin conjugates as a chemical sterilant.

2) To demonstrate the feasibility of such control in a field application at the Rocky Mountain Arsenal.

3) To predict population impacts of alternative contraceptive regimes using simulation modeling.

This research project consists of laboratory, field, and modeling phases, each designed to address questions that must be answered before application of hormonal-toxin conjugates to mule deer populations at the Rocky Mountain Arsenal.

Laboratory Phase

The sexual cycle in mammals is completely dependent on the gonadotropin hormones secreted by cells in the anterior pituitary gland. Two important gonadotropic hormones include follicle stimulating hormone (FSH) and luteinizing hormone (LH). These two hormones control proper functioning of ovaries in females and testes in males.

In all mammals studied, control of gonadotropin secretion is mediated by production and release of GnRH in the hypothalamus. By coupling a superactive analog of GnRH to a cytotoxin, it should be possible to specifically target that toxin to FSH- and LH-secreting cells in the anterior pituitary gland, thereby preventing successful reproduction.

At present, manufacturing GnRH-toxin conjugates is done at laboratory rather than commercial scales. Because hormonal-toxin production is costly, it is imperative to determine the minimum dose that will provide consistent effects. To accomplish this, analogs of GnRH that have a biological potency 60 times greater than natural GnRH will be linked to a toxin to form a potential chemical sterilant. Using an analog with greater biological potency will increase the efficiency of delivering toxin conjugates to gonadotrophs in the anterior pituitary gland, thus reducing the quantity of toxin needed for treatment of an individual animal.

During this phase of research, we will conduct controlled experiments with captive penned mule deer to determine the most effective dose of GnRH-toxin conjugates. We will evaluate the stage of the reproductive cycle when the chemical sterilant is most effective as well as duration of effectiveness. Finally, we will use these studies to evaluate the safety and side effects (if any) of treatment. All studies in the laboratory phase will be conducted at the Department of Physiology at Colorado State University, and the Colorado Division of Wildlife's Foothills Wildlife Research Facility, in Ft. Collins, Colorado.

Experiment 1: Dose Responses During Estrous

The amount of GnRH analog needed to induce half-maximal release of gonadotropic hormones is not known for deer. In order to estimate of the dose of GnRH-toxin conjugate required for sterilization, it is essential to determine the potency of GnRH analog. This experiment will be conducted during the peak of breeding season to insure that the pituitary gland is at its most active state when stimulated by GnRH analog.

Experiment 2: Dose Responses During Anestrous

Cells in the pituitary are most susceptible to GnRH-toxin treatment when they are most active. This occurs during the peak of the breeding season, in late autumn. For a variety of reasons, however, it may be necessary to treat animals in the field when they can be trapped effectively. This may occur later in winter when animals are less reproductively active. This experiment will evaluate effects of season on performance of the GnRH analog. If response of the pituitary is similar to that observed during the breeding season (estrous cycle), then GnRH-toxin conjugate could be administered without regard to season of year.

Here, we report results of two preliminary experiments. Our primary objectives were to determine the most effective dose of GnRH-toxin conjugate for mule deer and test the null hypotheses that there is no effect of season on the response of deer to this dose. Additionally, the availability of captive elk (*Cervus elaphus*) at our research facility provided an opportunity to expedite development of experimental techniques on a similar species prior to conducting trials with mule deer.

METHODS AND MATERIALS

Experiment 1

We conducted experiments to measure pituitary response to hypothalamic-gonadotropin releasing hormone analogs in mule deer and elk during the breeding season. For seasonally breeding, polyestrous ungulates, such as deer and elk, this occurs in the fall. We conducted trials with elk from September 17 to October 19; mule deer from November 9 to December 11, 1991. We estimated the peak of conception to be about September 25 in our captive elk and December 1 for mule deer.

We measured LH responses of mule deer and elk to five levels of GnRH analog in a randomized complete block design with a repeated measures structure. Levels of GnRH analog administered were 0 (control), 0.3, 1.0, 3.0, and 10 micrograms/50kgBW. Based on information from studies on other animals, we chose a range of doses of this analog that should include the biologically effective range for mule deer and elk. All treatments were administered on the same day to all animals. Trials were conducted every 8 days.

Five tame, sexually mature mule deer (3 non-pregnant females; 2 male castrates) and elk (5 non-pregnant females) were sedated with xylazine hydrochloride and fitted nonsurgically with indwelling jugular catheters. Concentrations of LH in serum were measured at 0 (immediately prior to treatment), 30, 60, 90, 120, 180, 240, 300, and 360 minutes post-treatment. Blood was allowed to clot at room temperature prior to centrifugation. Serum was harvested the next day and frozen at -20C.

All serum samples were analyzed for LH concentrations using radioimmunoassay (Niswender et al. 1969). The LH response to treatment doses of GnRH analog was assessed by 1) estimating the maximum concentration released (peak of LH dose response curve), 2) time interval from injection of GnRH bolus to peak LH concentration, and 3) the total amount of LH released (estimated by calculating the area under the LH curve).

Response to treatment was analyzed with a two-way factorial analysis of variance for a randomized complete block design with 5 levels of dose as treatments and 5 individual animals as blocks. Factors in the analysis were dose and time. Time was treated as a within subject effect using a multivariate approach to repeated measures (Morrison 1976). We used a priori orthogonal contrast to test for differences among individual means.

Experiment 2

We conducted experiments with mule deer and elk to evaluate the responsiveness of the pituitary gland to stimulation by GnRH analogs during the anestrous phase of the reproductive cycle. Previous studies with wild ungulates, suggest a reduction in ovarian activity beginning in mid-March for non-pregnant red deer (Cervus elaphus) (Kelly et al. 1982) and late April for white-tailed deer (Plotka et al. 1977). Based on these observations, we conducted trials from March 13 to April 14 with elk and April 4 to May 4 with mule deer.

Application of GnRH analog, blood sampling, and LH analysis were as described in Experiment 1, except that two additional sampling times (150 and 420 min) were added to better define the LH secretion curve. We used a paired Student's t-test to test the null hypothesis of no effect of season, paired within individual animals, and observations of LH production during both seasons formed the pairs used in the analyses.

RESULTS AND DISCUSSION

Experiment 1: Dose Responses During the Breeding Season

Mule Deer

Treatment of mule deer with GnRH agonist induced release of LH from the anterior pituitary. The pattern of LH release over time varied considerably between females (Figs.1-5) and male castrates (Figs.6-10) and among individuals of both sexes. Castrated males generally exhibited higher baseline concentrations of LH (Table 1) and more prolonged response to GnRH analogs than females. Regardless of sex, LH began to increase 30 minutes after administration of GnRH, with the maximum concentration occurring between 180 and 237 minutes post-injection (Table 2). Time from injection of GnRH bolus to peak concentration was highly variable among all deer but generally appears to be related to increasing dose.

LH response curves were generally not well-defined for castrate deer for any level of GnRH analog. This made it difficult to calculate peak concentrations of LH and time required to reach these peaks. Non-pregnant females, on the other hand, exhibited similar patterns of response to GnRH treatments; however, peak amplitude of LH response curves and time to peak LH differed among individuals (Table 1). This variation is consistent with the view that the number of receptors for GnRH in the anterior pituitary gland change with fluctuating concentrations of estradiol and progesterone (Moss et al. 1981). Estradiol (produced by developing follicles during estrous) increases the number of receptors for GnRH (Crowder and Nett 1981) whereas, progesterone produced by the corpus luteum agonizes this response. Therefore, variation in magnitude of the LH peak may be strongly related to phase of the estrous cycle when female deer in this experiment were sampled.

The small sample size and large variation among individual animals in this experiment precludes a definitive determination of the most effective dose of GnRH analog for mule deer. However, while peak amplitude of LH and the time to reach this peak varied among female deer, all showed similar trends in response to increasing levels of GnRH analog (Fig. 11). Peak concentrations of LH occurred at 1.0 microgram/50kgBW for all females and declined thereafter with increasing concentrations of GnRH.

Elk

Administration of exogenous GnRH analogs to non-pregnant elk during the breeding season induced release of LH from the anterior pituitary. In order to insure that maximum pituitary response was attained, we challenged elk with an additional dose of 30 micrograms/50kgBW of GnRH analog. This treatment was applied to mule deer and elk in Experiment 2 as well.

During the breeding season, peak concentrations of LH (Fig.12) and the total amount of LH released (Fig.13) occurred at a dose of 10.0 micrograms/50kgBW. However, no significant (P = 0.66) changes in serum LH were observed in elk challenged with doses of GnRH higher than 3.0 micrograms/50kgBW (Table 3,4). Average peak concentrations were reached at 189.4 + 20 min after injection (Table 5), then LH declined during the next 231 min and reached baseline concentrations at approximately 400 min. In general, however, time of peak concentration was poorly estimated for all animals, making analysis and interpretation of this variable unreliable. No significant treatment x trial interaction was observed for peak concentration, time of peak or total LH released (P = 0.33). These results suggest that 3.0 micrograms/50kgBW of GnRH analog would be effective in stimulating pituitary response of sexually mature, non-pregnant elk throughout the breeding season.

Experiment 2: Dose Responses During Anestrous

Mule Deer

We were not able to determin an effective dose of GnRH analog for mule deer during anestrous due to an inadequate sample size and large variation in LH response among individual animals. Three of the adult female mule deer to be used in this experiment were accidently bred by a six-month old male fawn prior to spring trials. One of these females died during the study from causes not related to experimental treatments (renal failure). Moreover, we replaced the male castrates from Experiment 1 with two, 10 month-old female fawns.

Due to the above confoundments and resulting heterogeneous group of experimental deer, we abandoned our original objectives and attempted to simply describe the LH response of pregnant and non-pregnant mule deer to different concentrations of GnRH analogs. By challenging fawns with GnRH we were able to evaluate the responsiveness of the pituitary in sub-adult females. This information will be used in future studies to establish a statistically acceptable sample size and experimental design.

Average baseline concentrations and patterns of LH release were similar in pregnant and non-pregnant deer, however, peak concentrations of LH were considerably higher for non-pregnant fawns, particularly for doses of GnRH analogs higher than 1.0 microgram/50kgBW (Table 4). Peak concentration of LH occurred at a dose of 3.0 micrograms/50kgBW for pregnant deer; 1.0 for non-pregnant fawns, then remained relatively constant with increasing levels of GnRH (Fig.14). Time of peak concentration did not appear to be related to level of GnRH (Table 7).

Elk

Treatment of anestrous elk with analogs of gonadotropin-releasing hormone induced release of LH from the pituitary, however, more GnRH analog was needed to induce peak concentration, and total amount of LH compared to cyclic elk during the breeding season (Table 3,4). We observed significant (P = 0.001) increases in peak concentration and total amount of LH released for each treatment up to a dose of 10 micrograms/50kgBW. Pituitary response then declined but not significantly (P > 0.26) for the highest dose of GnRH administered (30 microgram/50kgBW)(Fig. 12,13). Time interval (min) to peak concentration of LH was highly variable and did not permit meaningful interpretation (Table 5). Similar to Expt.1, we did not observe a treatment x trial interaction for any of the responses we measured (P = 0.38). These observations suggest that the same dose of GnRH analog should be effective throughout the anestrous period.

We reject the null hypotheses that there is no effect of season on the response of elk to GnRH analogs. We observed significant (P = 0.001) declines in peak concentration and total LH released for anestrous elk challenged with GnRH doses of 0.3, 1.0, and 3.0 micrograms/50kgBW (Table 3,4). At higher doses, pituitary responses of anestrous and cyclic elk were similar (P = 0.62). During anestrous, it required almost three times as much GnRH analog to elicit the same LH response as that required during the breeding season.

The diminished responsiveness to GnRH may be related to the inhibitory effects of longer photoperiod on the reproductive axis. Increasing photoperiod inhibits melatonin secretion from the pineal gland which in turn decreases secretion of GnRH from the hypothalamus. This leads to reduced LH and FSH secretion resulting in lack of ovarian activity (i.e. no follicles therefore no estradiol). The lack of estradiol and reduced secretion of GnRH both lead to a reduction in the number of receptors for GnRH, and ultimately to decreased pituitary responsiveness (Gregg and Nett 1989). Collectively, this suggests that a larger dosage of GnRH-toxin conjugate will be needed to induce sterility in elk during the anestrous season than during the breeding season.

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Table 1. Peak concentrations (ng/ml) of luteinizing hormone after administration of analogs of gonadotropin-releasing hormone to non-pregnant female (n=3) and male castrate (n=2) mule deer during the breeding season[c].

	Peak Concentrations of LH (ng/ml)			
	Female Deer		Male Castrate Deer	
Dose[a]	Mean	S.E.	Mean	S.E.
0.0[b]	0.19	0.02	1.31	0.09
0.3	6.30	3.40	2.56	1.50
1.0	20.32	10.57	5.33	2.23
3.0	9.25	3.41	6.12	3.27
10.0	12.70	6.92	7.34	2.84

[a]Dose = micrograms/50kgBW
[b]Average baseline LH concentration was calculated for the control dose.
[c]Means were not significantly different (P> 0.05).

Table 2. Time interval (min) after administration of analogs of gonadotropin-releasing hormone to peak concentration (ng/ml) of luteinizing hormone in non-pregnant female (n=3) and male castrate (n=2) mule deer during the breeding season[b].

	Time Interval to Peak Concentration (min)			
	Female Deer		Male Castrate Deer	
Dose[a]	Mean	S.E.	Mean	S.E.
0.0	---	---	---	---
0.3	180	34.40	188	24.54
1.0	201	19.57	193	98.25
3.0	182	1.76	210	28.58
10.0	219	22.67	237	62.68

[a]Dose = micrograms/50kgBW
[b]Means were not significantly different (P > 0.05).

Table 3. Peak concentrations of luteinizing hormone following administration of analogs of gonadotropin-releasing hormone to sexually mature, non-pregnant elk (n=5) during the breeding season and anestrous.

	Peak Concentration of LH (ng/ml)	
Dose[a]	Breeding Season	Anestrous
0.0[b]	0.15[c1]	0.10[c1]
0.3	1.76[d1]	0.59[d2]
1.0	20.30[e1]	2.35[e2]
3.0	27.14[f1]	10.07[f2]
10.0	29.19[f1]	32.43[g1]
30.0	23.62[f1]	22.64[g1]

[a]Dose = micrograms/50kgBW

[b]Average baseline LH concentration was calculated for the control dose.

[c,d,e,f,g]Means within columns with different lower case letters indicate significant differences ($P < 0.05$) among doses.

[1,2]Means within rows with different numbers indicate significant differences ($P < 0.05$) between phases of the reproductive cycle.

Table 4. Total amount of luteinizing hormone released following administration of analogs of gonadotropin-releasing hormone to sexually mature, non-pregnant elk (n=5) during the breeding season and anestrous.

	Total Amount of LH Released (ng/ml/min)	
Dose[a]	Breeding Season	Anestrous
0.0[b]	--------	--------
0.3	331.8[c1]	95.78[c2]
1.0	3152.1[d1]	382.60[d2]
3.0	4466.4[e1]	1980.61[e2]
10.0	4722.2[e1]	4905.50[f1]
30.0	4055.5[e1]	4139.66[f1]

[a]Dose = micrograms/50kgBW

[b] Total amount of LH released was not calculated for the control dose.

[c,d,e,f]Means within columns with different lower case letters indicate significant differences (P< 0.05) among doses.

[1,2]Means with rows with different numbers indicate significant differences (P< 0.05) between phases of the reproductive cycle.

Table 5. Time interval (min) after administration of analogs of gonadotropin-releasing hormone to peak concentration of luteinizing hormone in sexually mature, non-pregnant elk (n=5) during the breeding season and anestrous[c].

	Time Interval to Peak Concentration (min)	
Dose[a]	Breeding Season	Anestrous
0.0[b]	--------	--------
0.3	151.2	101.4
1.0	170.8	133.6
3.0	155.4	140.4
10.0	167.6	160.8
30.0	156.6	189.4

[a]Dose = micrograms/50kgBW

[b]Time interval to peak LH could not be calculated for control dose.

[c]Means within columns and between rows were not significantly (P> 0.05) different.

Table 6. Peak concentrations (ng/ml) of luteinizing hormone after administration of analogs of gonadotropin-releasing hormone to pregnant (n=2) and non-pregnant (n=2) mule deer during anestrous.

	Pregnant Deer		Non-pregnant Deer	
Dose[a]	Mean	S.E.	Mean	S.E.
0.0[b]	0.08	0.00	0.10	0.00
0.3	0.42	0.08	1.16	0.06
1.0	2.15	1.12	3.03	0.01
3.0	3.44	0.56	13.64	2.84
10.0	3.64	1.47	10.44	1.33
30.0	3.32	1.36	9.58	3.51

[a]Dose = micrograms/50kgBW

[b]Average baseline LH concentration was calculated for the control dose.

Table 7. Time interval (min) after administration of analogs of gonadotropin-releasing hormone to peak concentration (ng/ml) of luteinizing hormone in pregnant (n=2) and non-pregnant (n=2) mule deer during anestrous.

	Pregnant Deer		Non-pregnant Deer	
Dose[a]	Mean	S.E.	Mean	S.E.
0.0	----	----	----	----
0.3	149.5	31.60	133.0	14.10
1.0	149.5	0.50	240.5	0.00
3.0	185.5	0.00	240.5	0.00
10.0	271.5	29.5	162.5	16.50
30.0	242.0	58.2	240.5	0.00

[a]Dose = micrograms/50kgBW

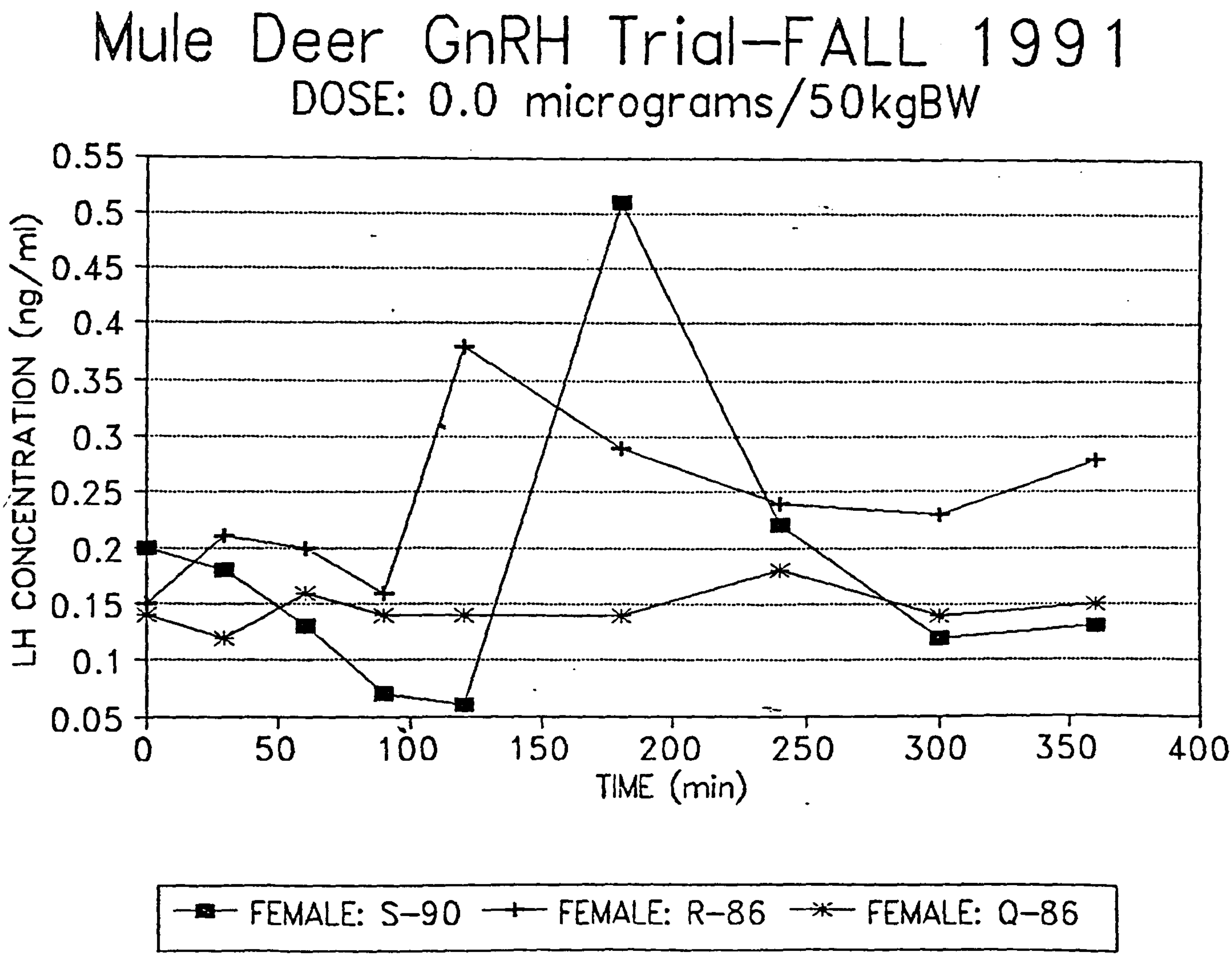

Figure 1. Baseline serum LH concentrations of 3 non-pregnant sexually mature mule deer given a dose of 0.0 micrograms/50kgBW (control) of GnRH analog.

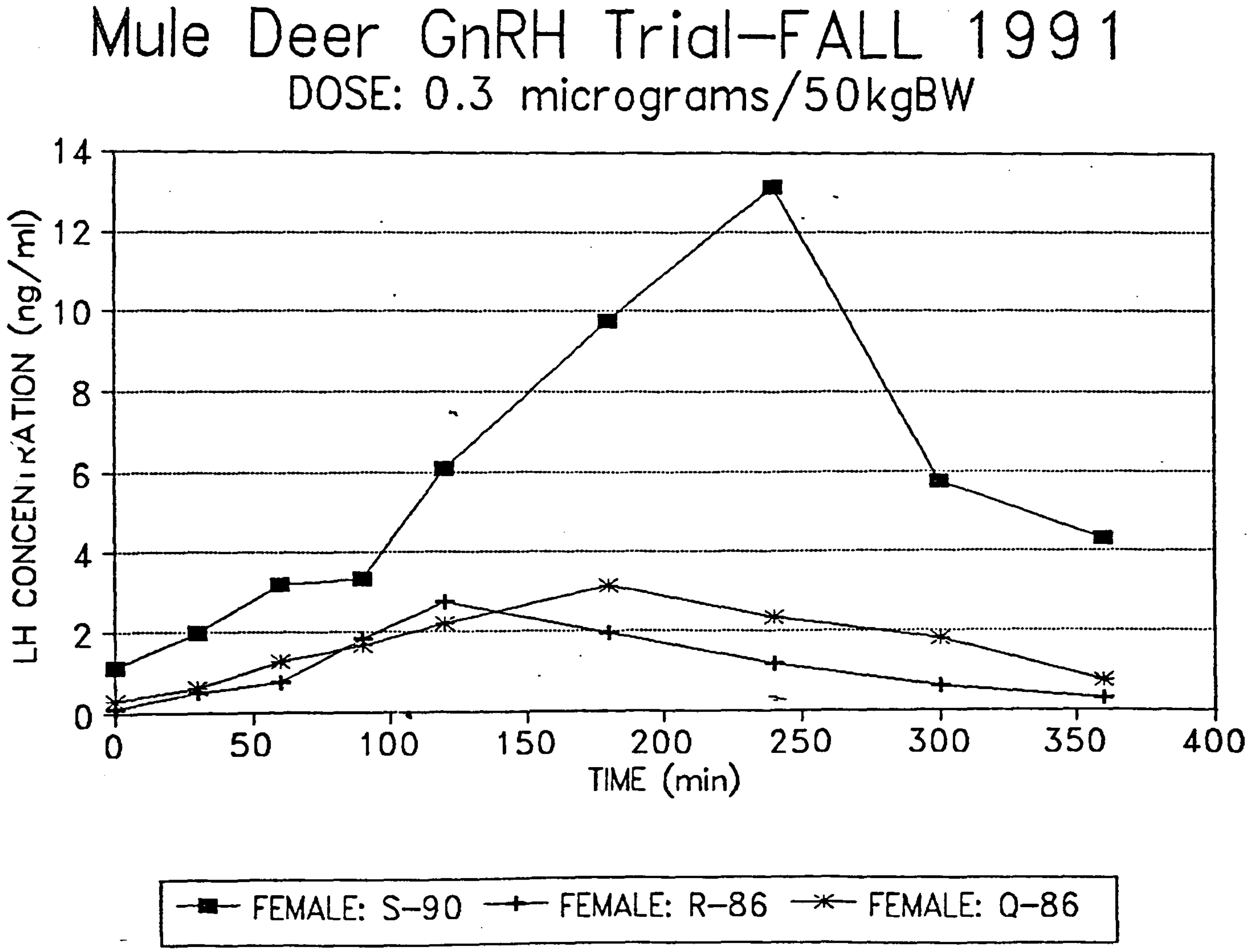

Figure 2. Serum LH concentrations of 3 non-pregnant sexually mature mule deer given a dose of 0.3 micrograms/50kgBW of GnRH analog.

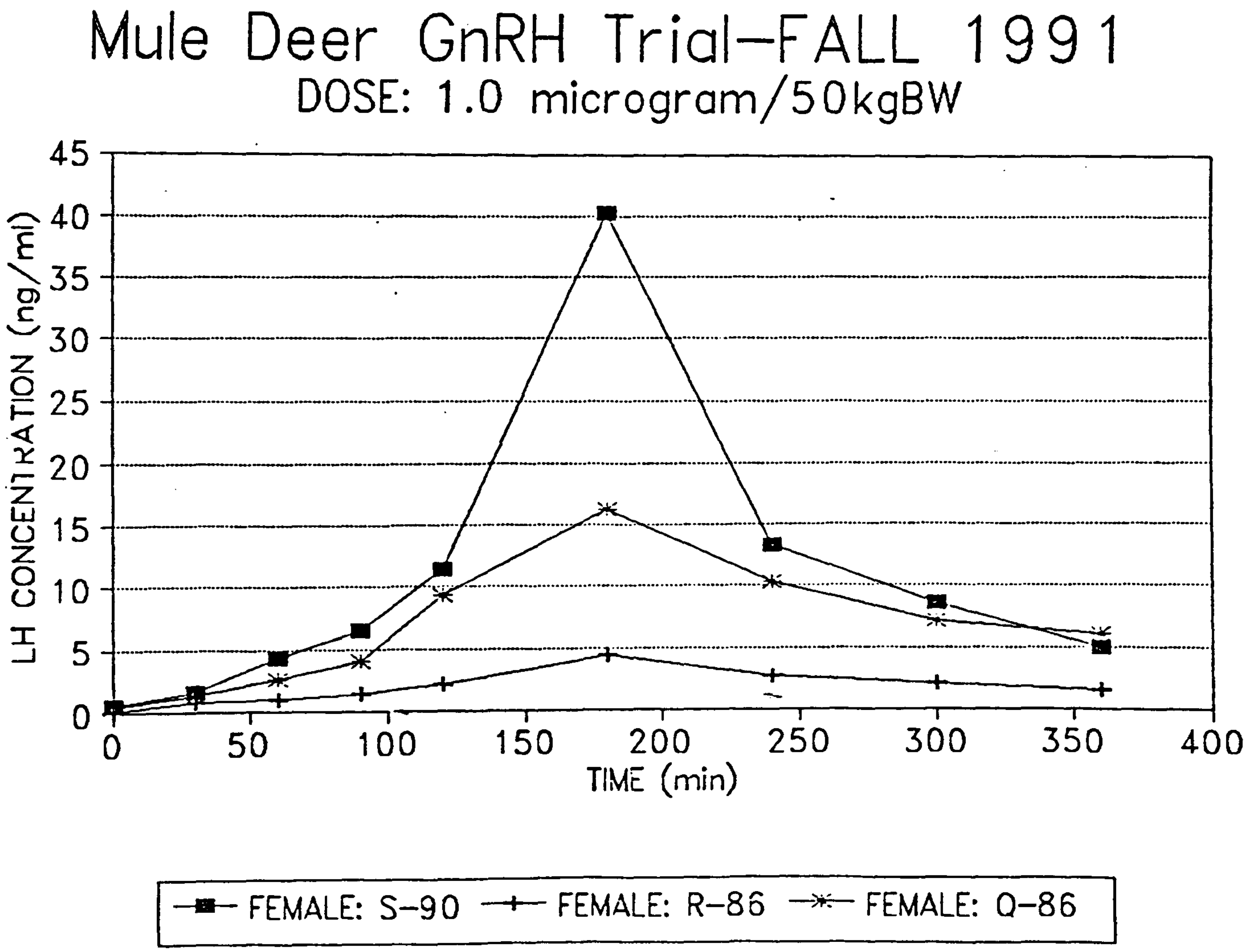

Figure 3. Serum LH concentrations of 3 non-pregnant sexually mature mule deer given a dose of 1.0 microgram/50kgBW of GnRH analog.

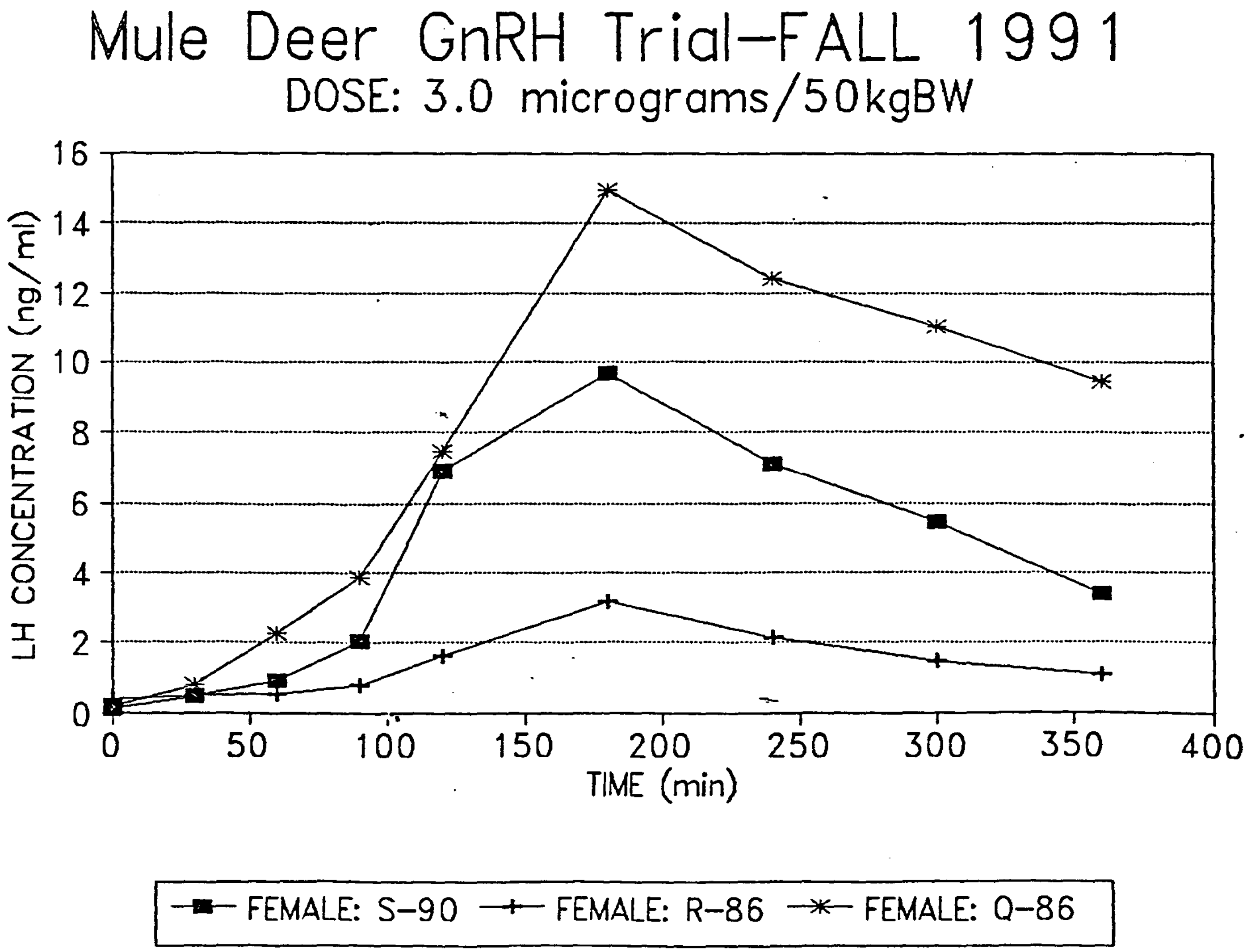

Figure 4. Serum LH concentrations of 3 non-pregnant sexually mature mule deer given a dose of 3.0 micrograms/50kgBW of GnRH analog.

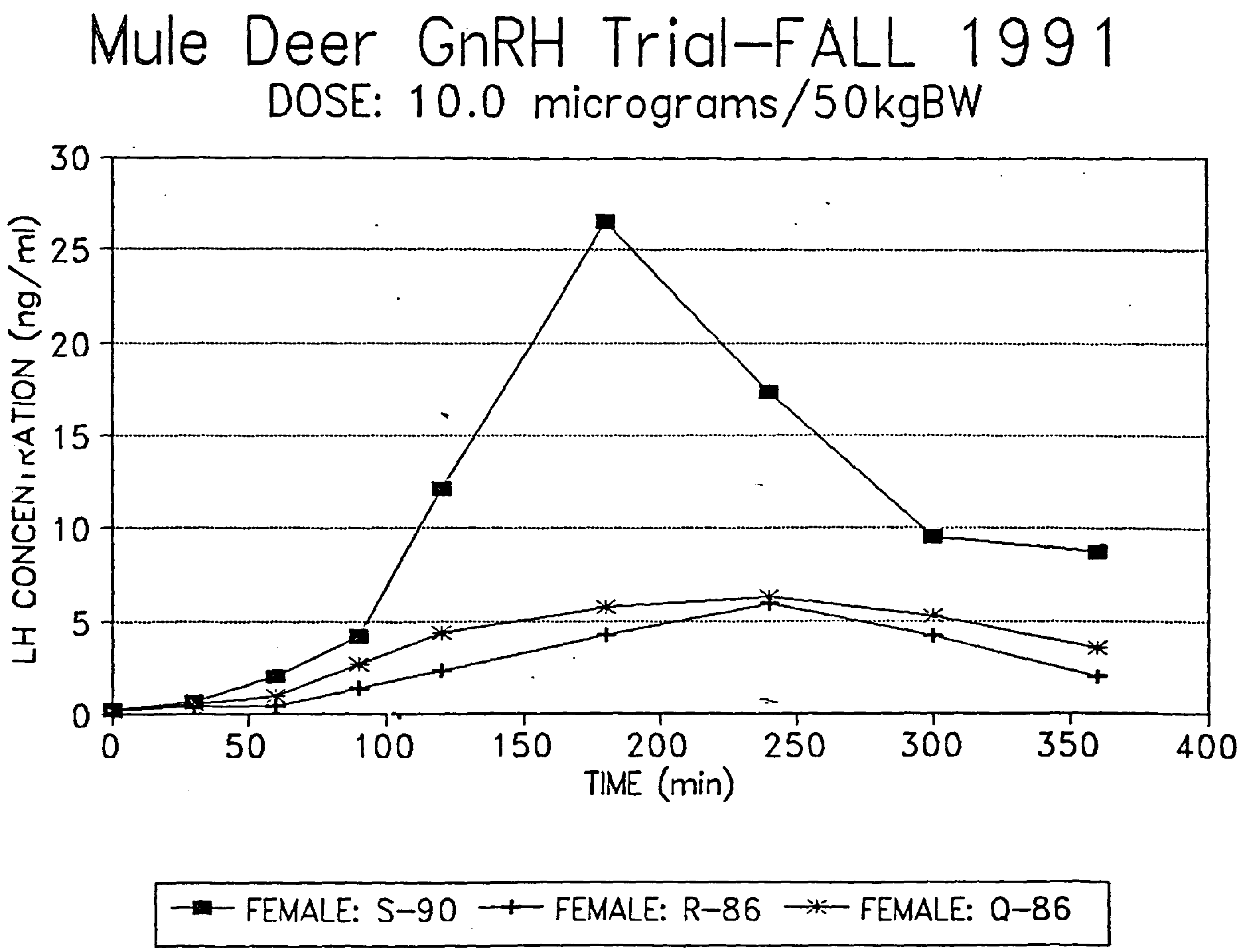

Figure 5. Serum LH concentrations of 3 non-pregnant sexually mature mule deer given a dose of 10.0 micrograms/50kgBW of GnRH analog.

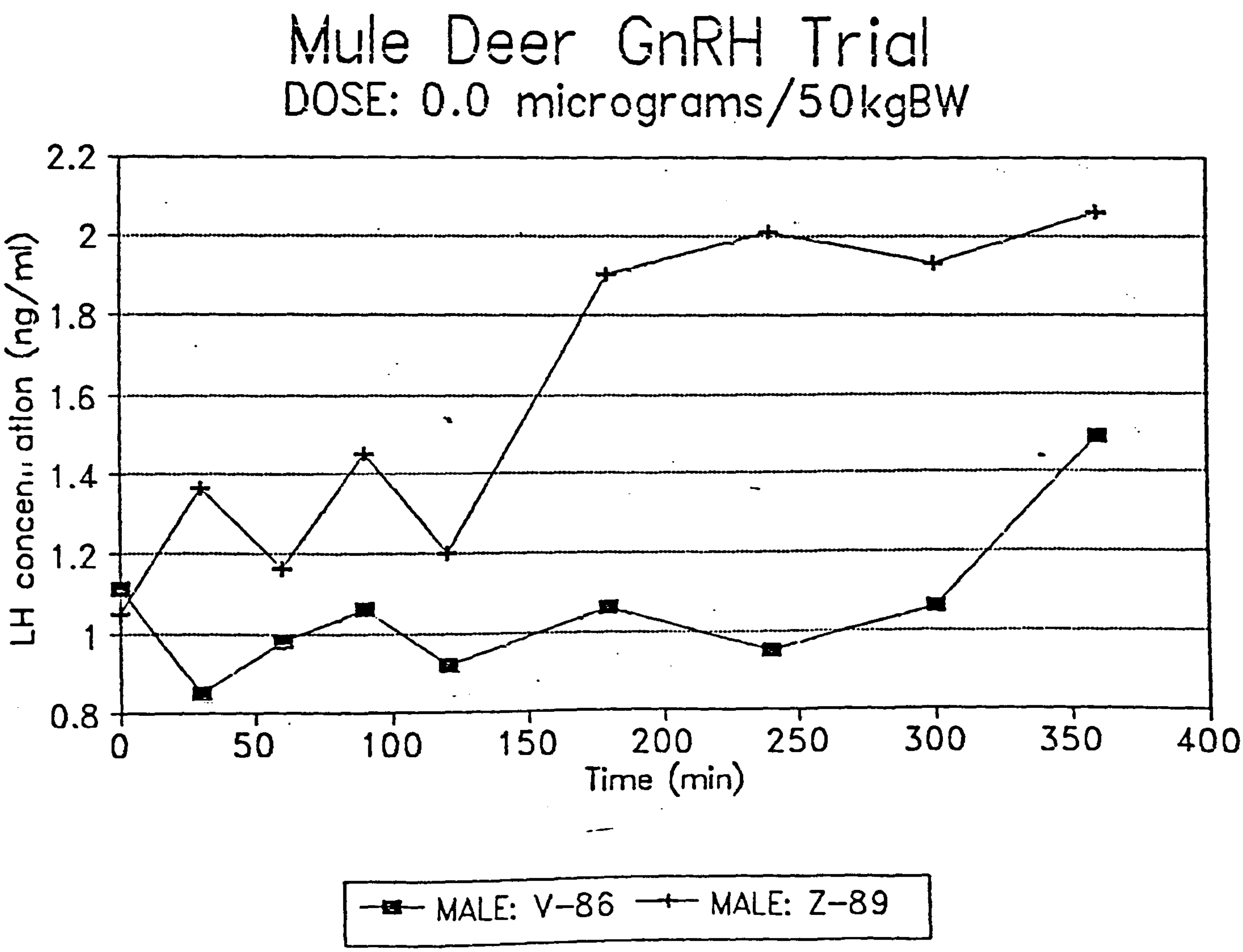

Figure 6. Baseline serum LH concentrations of 2 castrated mule deer given a dose of 0.0 micrograms/50kgBW (control) of GnRH analog.

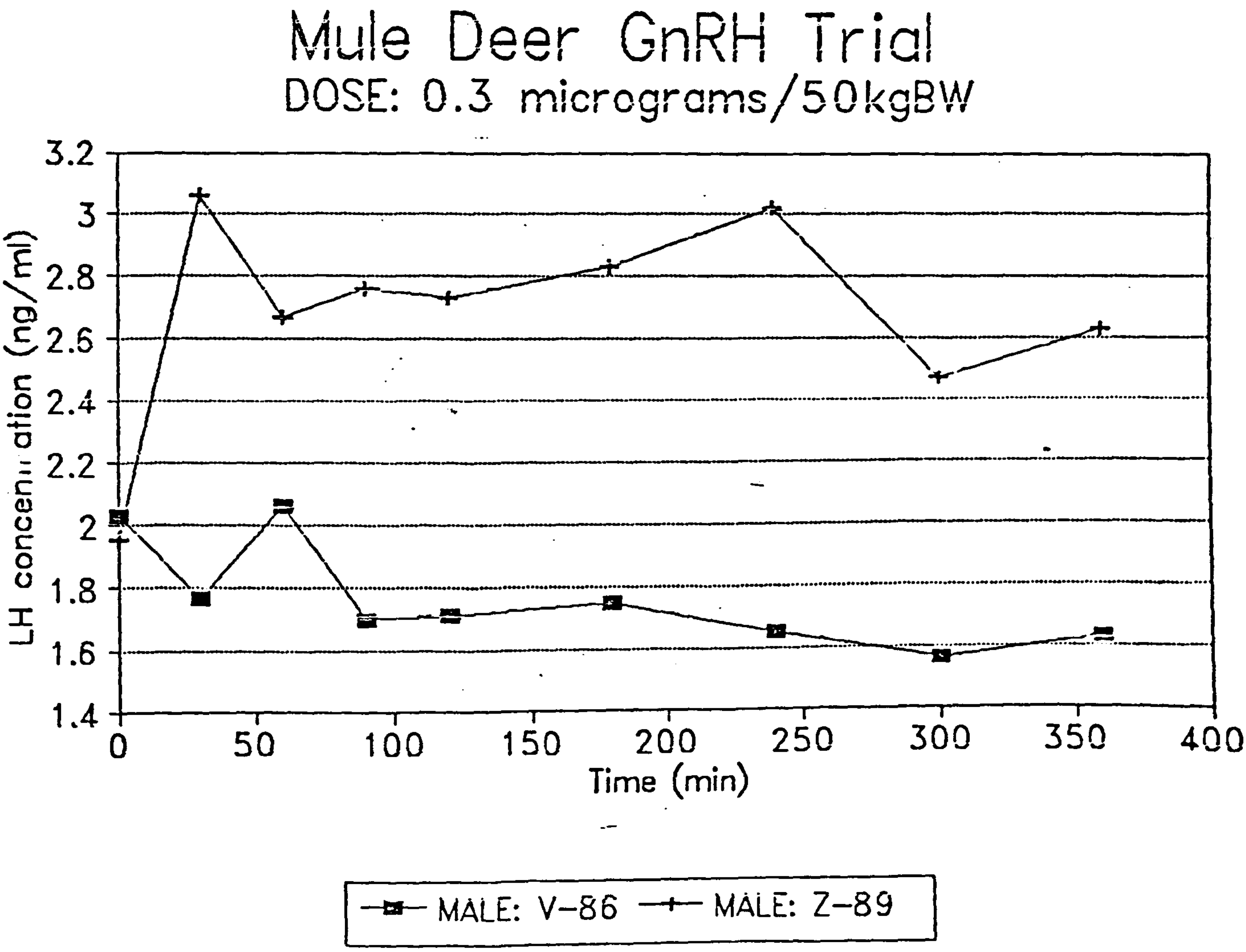

Figure 7. Serum LH concentrations of 2 castrated mule deer given a dose of 0.3 micrograms/50kgBW of GnRH analog.

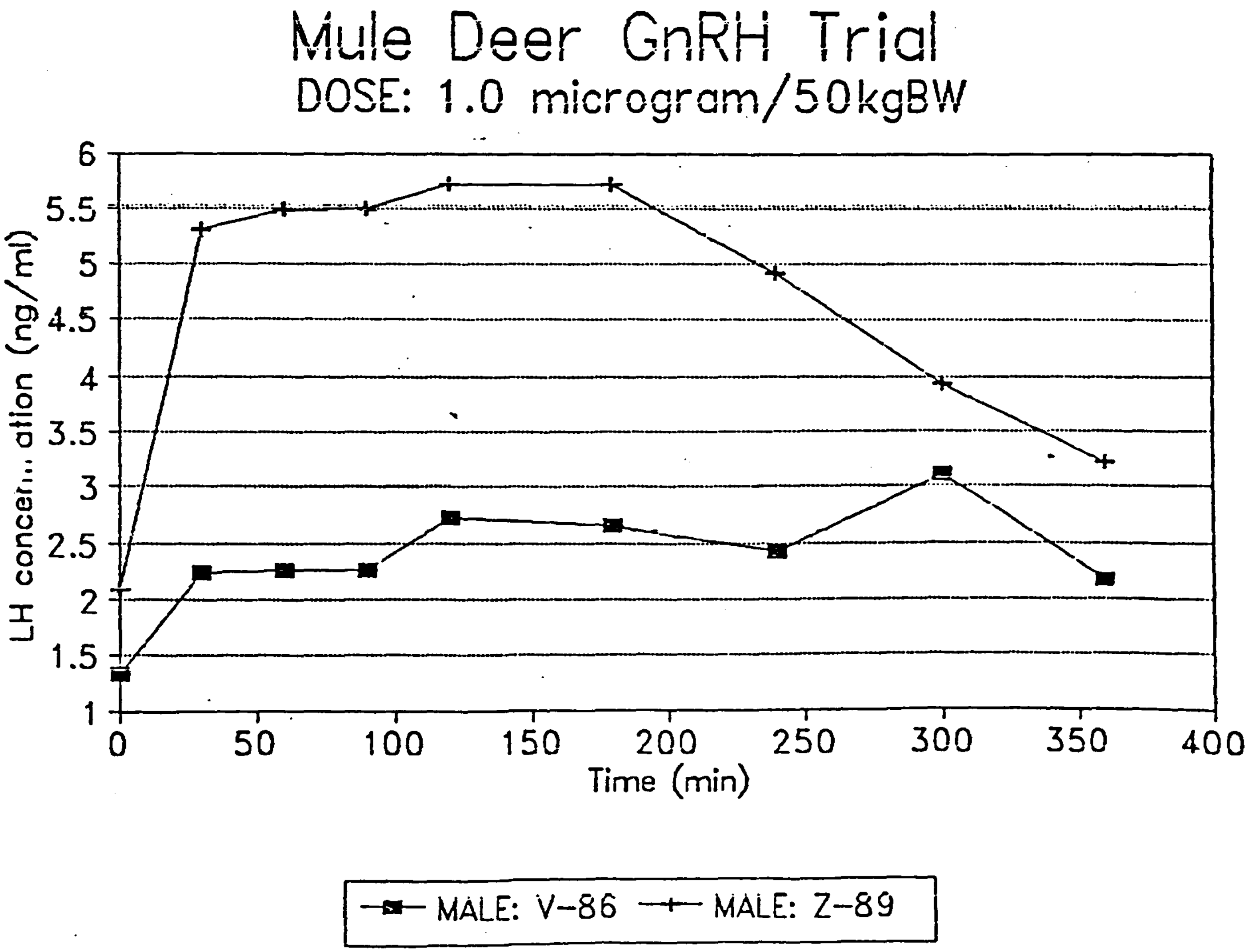

Figure 8. Serum LH concentrations of 2 castrated mule deer given a dose of 1.0 microgram/50kgBW of GnRH analog.

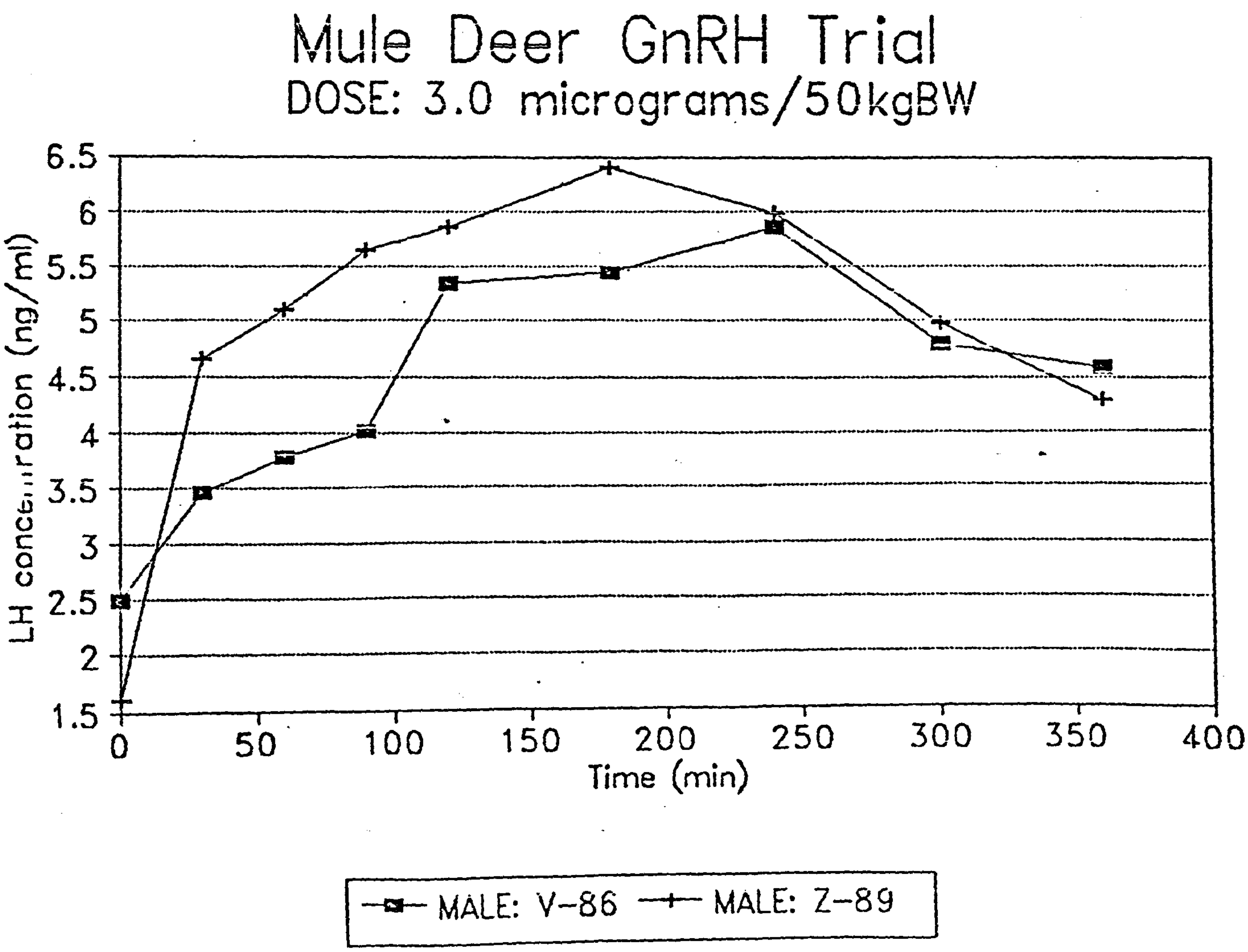

Figure 9. Serum LH concentrations of 2 castrated mule deer given a dose of 3.0 micrograms/50kgBW of GnRH analog.

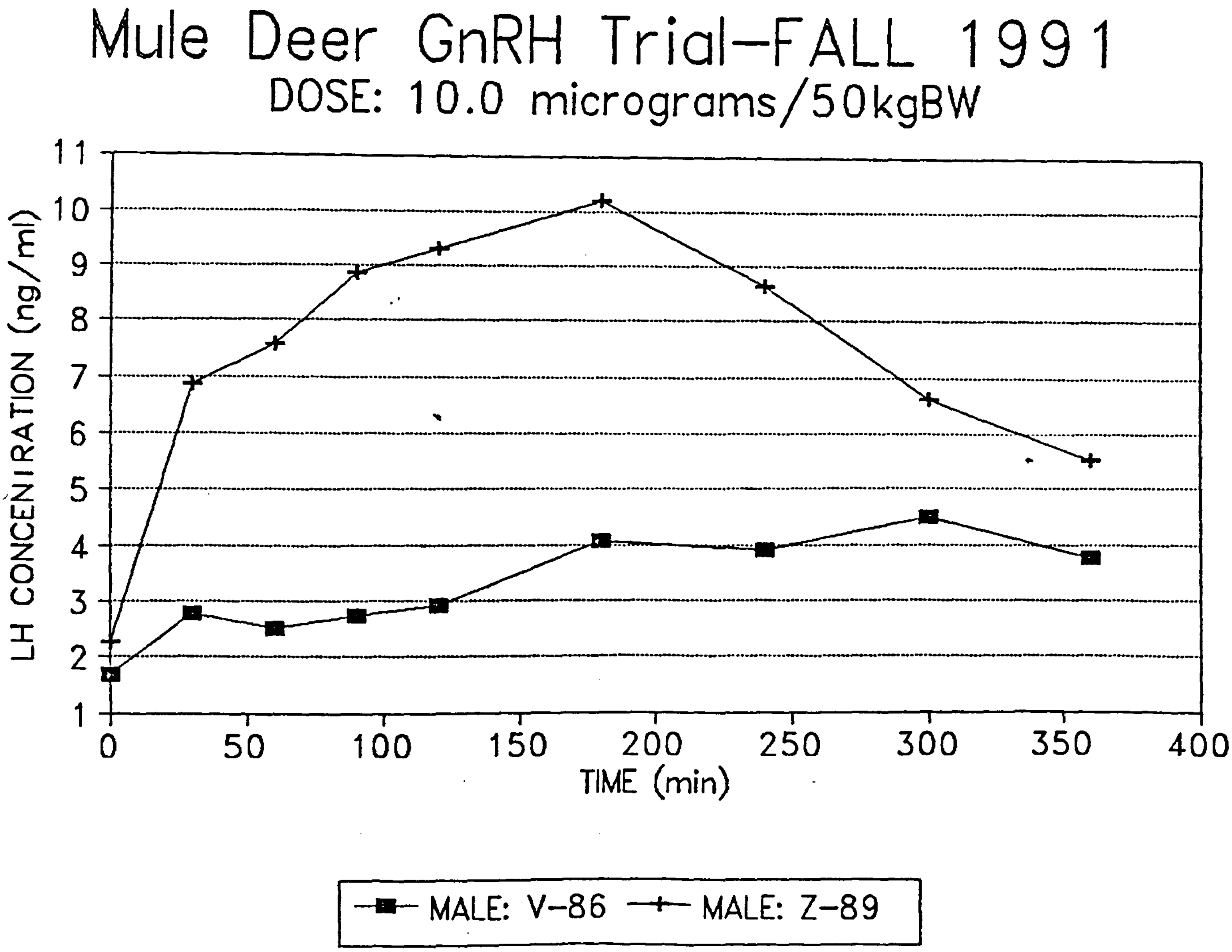

Figure 10. Serum LH concentrations of 2 castrated mule deer given a dose of 10 micrograms/50kgBW of GnRH analog.

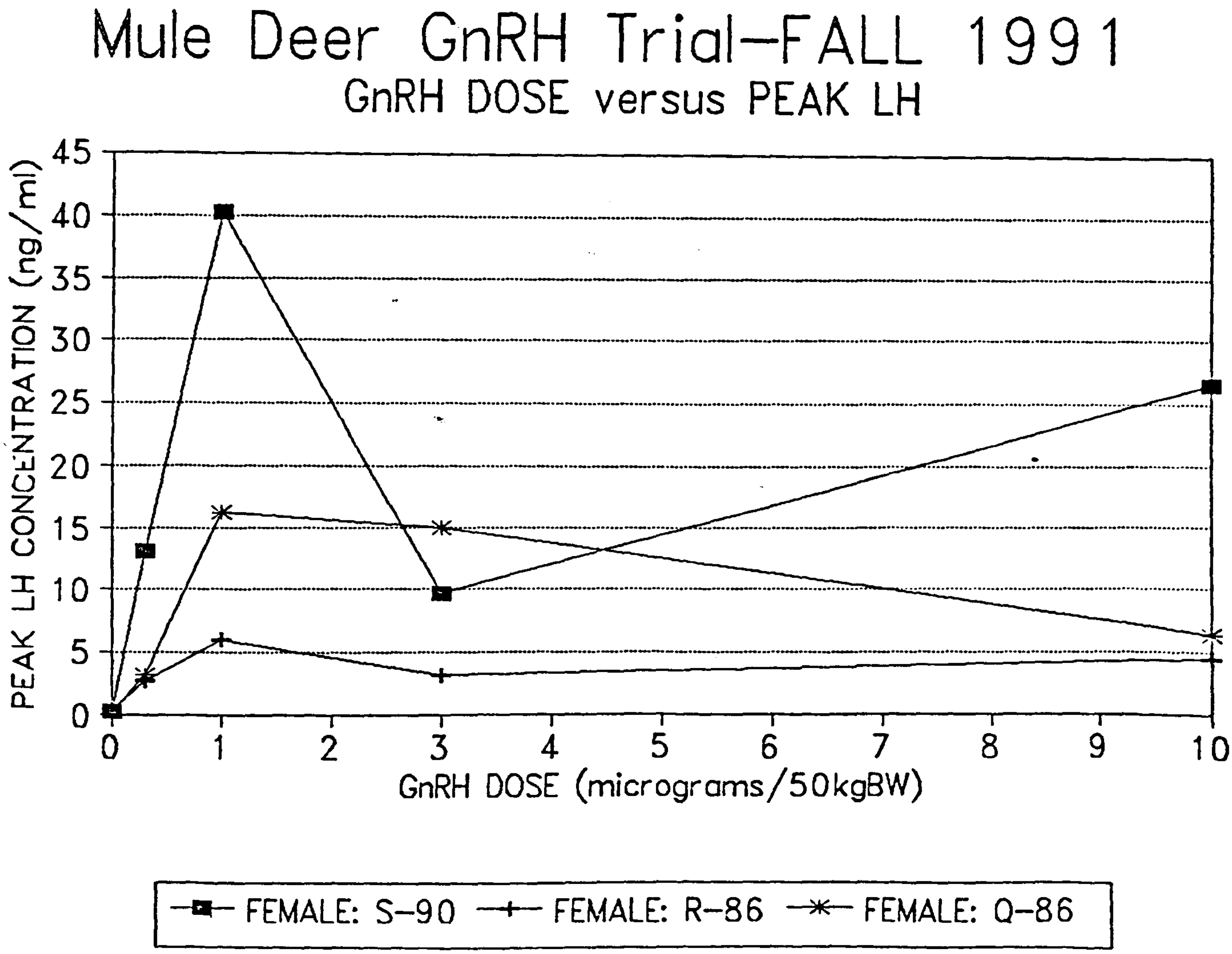

Figure 11. Peak serum LH concentrations (ng/ml) of 3 non-pregnant sexually mature mule deer challenged with 5 levels of GnRH analog.

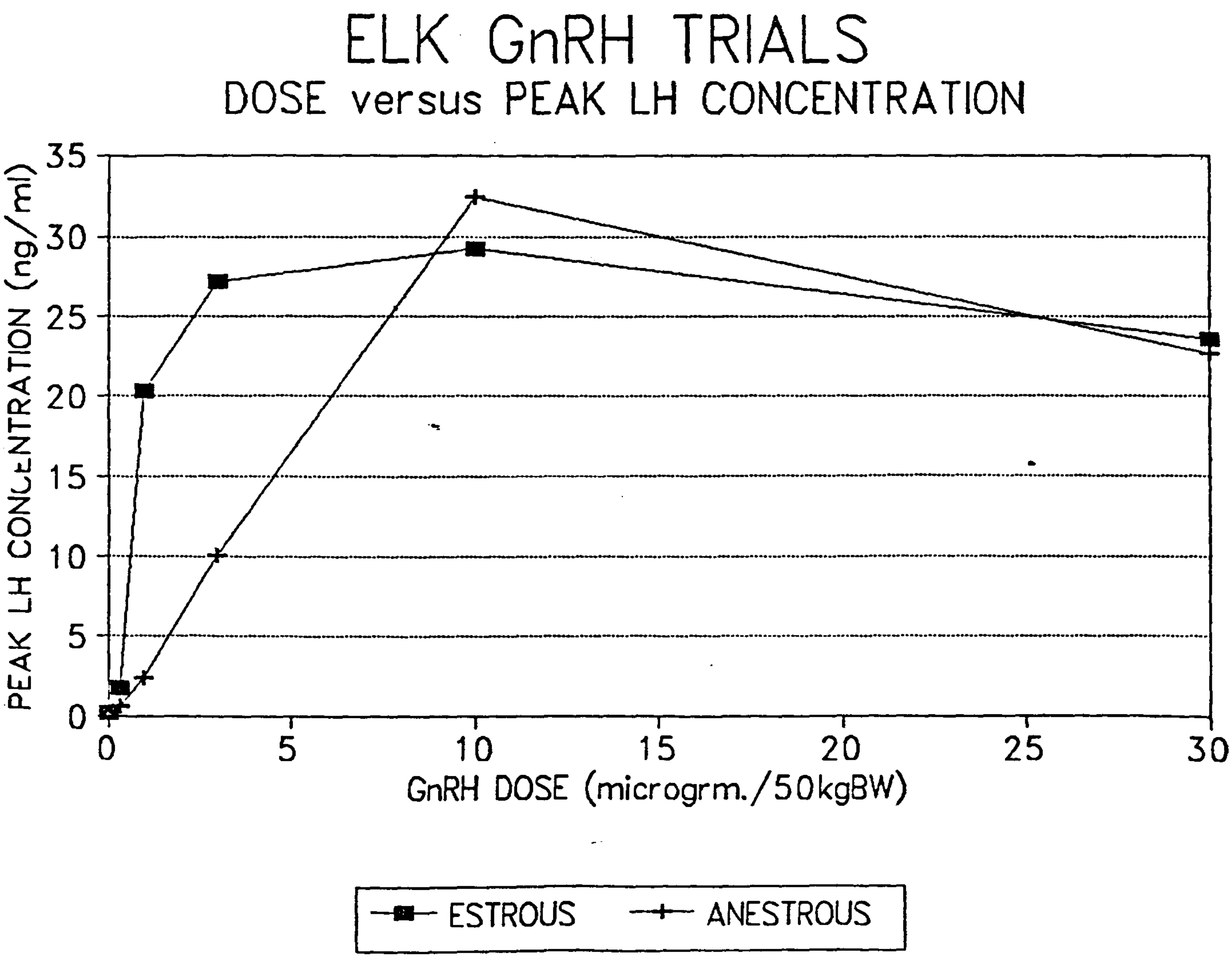

Figure 12. Peak concentrations of luteinizing hormone (ng/ml) after administration of analogs of gonadotropin-releasing hormone to sexually mature, non-pregnant elk (n=5) during estrous and anestrous.

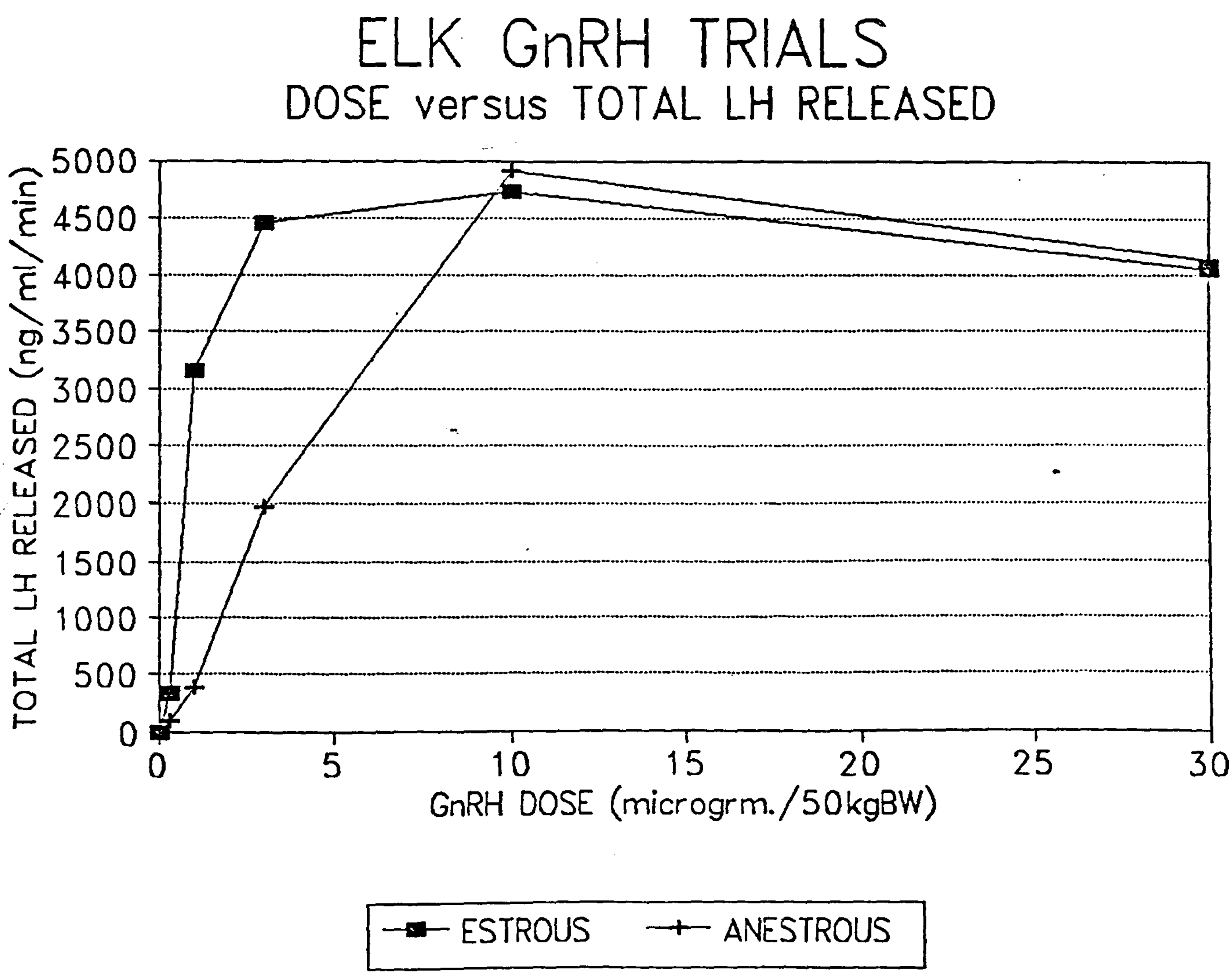

Figure 13. Total luteinizing hormone release (ng/ml/min) after administration of analogs of gonadotropin-releasing hormone to sexually mature, non-pregnant elk (n=5) during estrous and anestrous.

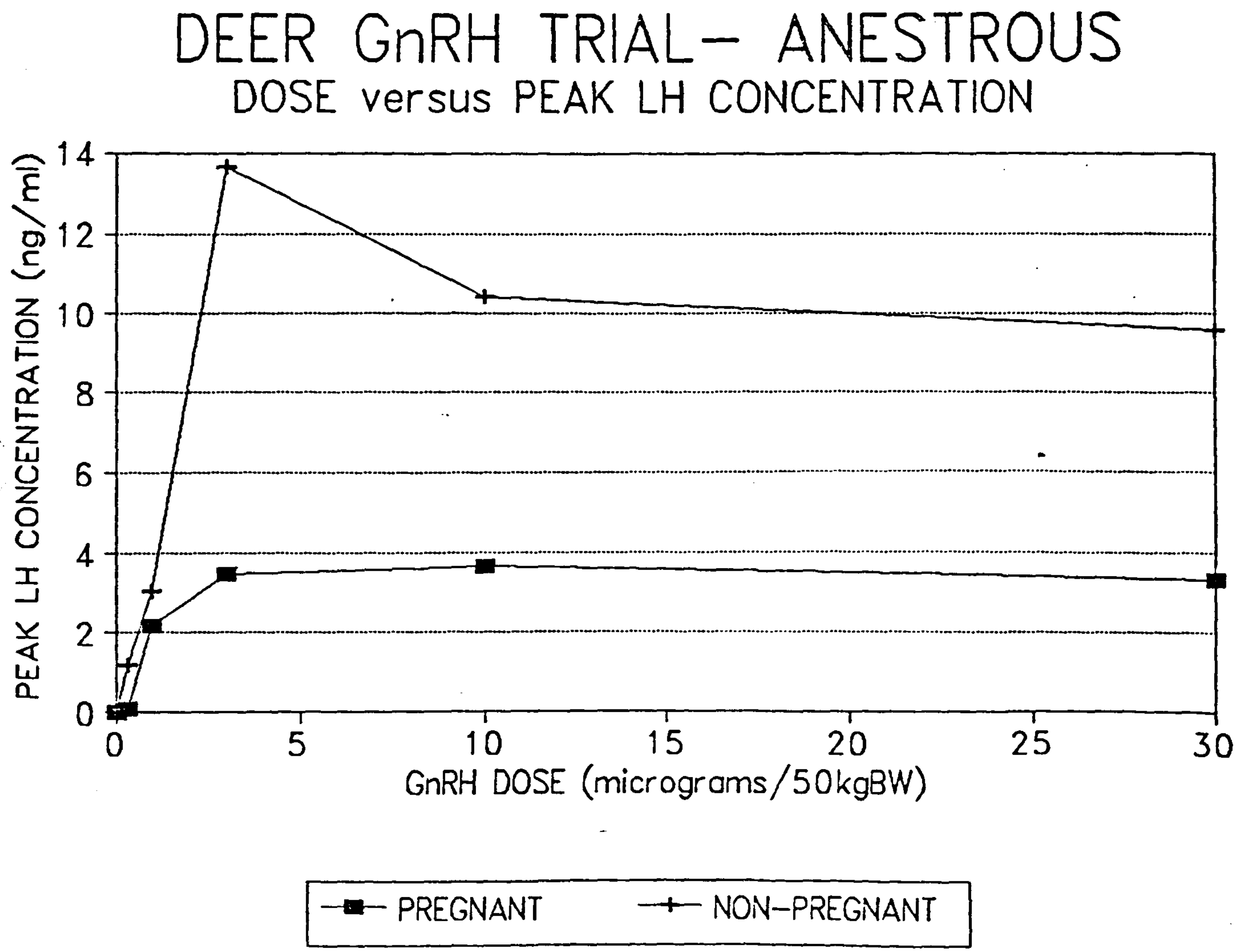

Figure 14. Peak concentrations of luteinizing hormone (ng/ml) after administration of analogs of gonadotropin-releasing hormone to pregnant (n=2) and non-pregnant (n=2) mule deer during anestrous.