Deer Surveys and Management at Rocky Mountain Arsenal National Wildlife Refuge 1995-2003: A Summary & Review

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INTRODUCTION

Deer herds at Rocky Mountain Arsenal National Wildlife Refuge are unusual is several aspects as compared with other herds and populations in Colorado and other western states. In March of 1990 a 2.5 meter-high chain link fence was constructed that completely surrounded the refuge. While deer have been known to leap over the fence on occasion, the herd has remained isolated from surrounding populations. Deer populations outside the refuge have likely dwindled as habitat has been rapidly converted into urban/suburban housing and industrial development. Thus, for practical considerations, the RMA deer herd can be considered a closed population with no immigration or emigration.

A second consideration is that habitat within the refuge boundaries has undergone drastic changes. Roughly 10 of the 27 square miles (37%) of refuge has undergone extensive RCRA & CERCLA superfund remediation. The result is that at any given time, some amount of suitable habitat has been taken out of production. In addition, ongoing efforts to establish and restore native prairie have altered some of the available forage and temporarily removed some areas from production.

At present hunting is not permitted at RMA. However, culling and removal of individuals for sampling of disease and contaminants has occurred periodically. The Refuge also initiated a cooperative agreement with the Colorado Division of Wildlife. This agreement was entered into for assistance with deer management issues on the Refuge and for the completion of testing a non-lethal method for controlling deer populations. As part of these efforts, annual classification surveys have been conducted since 1996 using three teams of two persons driving established routes (see Figure 1) for three days. Prior to 1995 helicopter surveys also attempted to count and classify deer by species, age and sex.

Recent results of these surveys have revealed a drastic reduction in herd recruitment (Figure 2). In 2002 for example, fawns per 100 does were as low as 6 and 2 (Mule Deer and White-tailed Deer respectively) compared with an average (1995-2003) of 46 and 30 respectively. This represents a severe decline that may result in future population crashes. There may be several reasons for the decline in recruitment which are not mutually exclusive. One reason may be that nutritional deficiencies during the winter are causing does to have fewer young (DelGiudice et. al 1991; Lesage et. al 2001; Swihart et. al. 1998; White and Lubow 2002). RMA, which is the site of on-going environmental cleanup, has large areas that are temporarily unsuitable deer habitat until native grassland vegetation can be reestablished.

Figure 1. Deer Classification Survey Routes

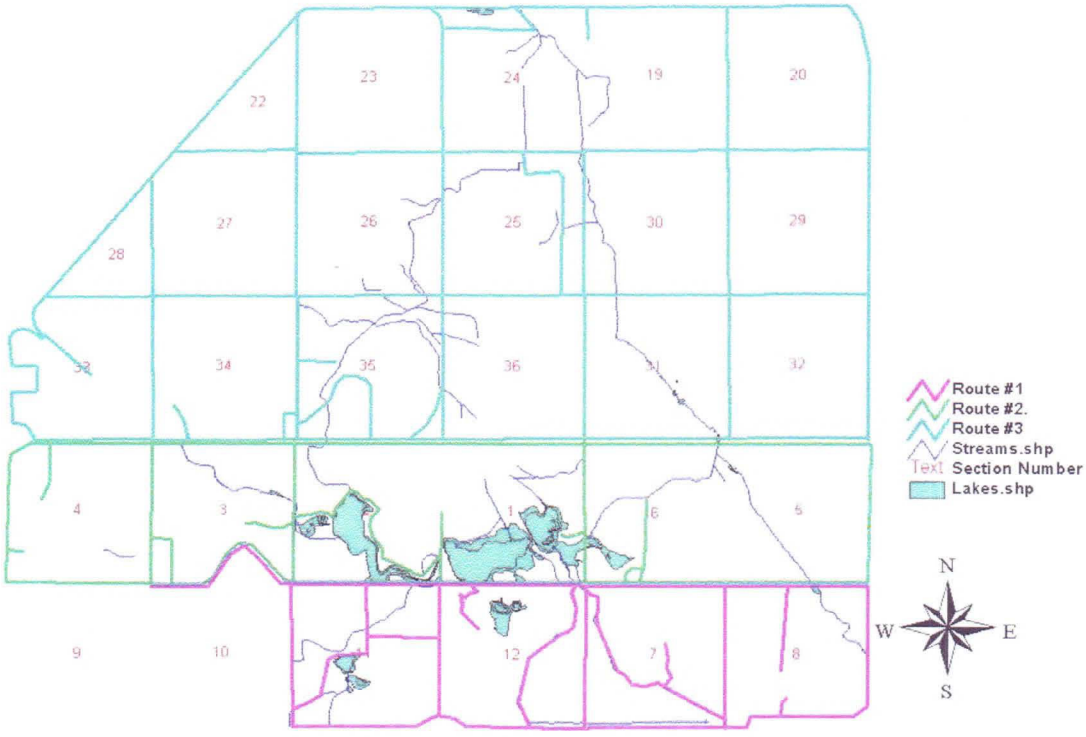


Figure 2. Deer Recruitment at RMANWR (1995-2003)



A second possibility is that deer demographics at RMA have affected recruitment rates. The RMA deer herd has aged because older deer have survived longer without hunting. These older deer, both bucks and does, are perhaps less able to produce fawns (Bowden et. al. 1984). More direct means of examining this possibility will be available in the near future from a study of fecundity rates among does. Presently we can examine correlations among Buck:Doe ratios and time series of recruitment rates as a means of indicating whether recruitment is declining due to an aging deer herd.

Still a third possibility is that the coyote population at RMA has grown and is preying more on young fawns, especially as their main prey, black-tailed prairie dogs (*Cynomys ludovicianus*), has declined due to recent outbreaks of plague (Ballard et. al. 2001, Hamlin et. al. 1984, Potvin et. al. 1981). Additive mortality from coyote predation on fawns could be examined simply by correlations of recruitment with coyote relative abundance, alternative prey numbers, or both. There is some indication that coyote populations have increased at RMA. Preliminary results of a scent station study suggests that coyote visitation rates have increased from 2.44% in a 1993-1994 survey to 9.76% in 2003-2004 ($p = 0.04$, Fisher's Exact test).

A fourth possibility is that the recent years of drought in Colorado have taken a toll on young fawns or altered the vegetation so that fawns are more vulnerable. Additional explanations may have something to do with climate or contaminants but clearly further investigation is warranted.

METHODS

As a first step in this process, survey and classification data were examined for correlations to several variables that might explain the recent decline in recruitment. Survey routes roughly divided the refuge into thirds. Three teams of two observers drove each route once on three non-consecutive days during the fall of each year (1996-2003). Records of deer observed were classified by group size (number of deer within 50 meters of each other), species, age, and sex. These records represent the basis for obtaining estimates of bucks per 100 does and fawns per 100 does for each species in each year.

Exploratory data analysis consists of several partial correlation matrices. Caution must be used in the interpretation of these results because of the large number of variables examined. When multiple correlations are made, the likelihood of obtaining a significant correlation by chance alone is greatly increased. Therefore, these analyses are meant only to suggest possible causes of reduced recruitment rather than to test specific hypotheses.

At the time of this report, neither data on the amount of RMA lands taken out of production or the relative number of predators (mainly Coyotes) is available. Herein, analyses are restricted to examining three general factors that may have influenced deer recruitment during the years from 1996 through 2003. These are 1) density-dependence, 2) predation and alternative prey availability, and 3) climate.

1. Density-Dependence

   Recruitment may be influenced by density dependent factors such as

overcrowding and depletion of resources. This would indicate that the RMA deer herd is at or near its carrying capacity. To examine this possibility three types of variables were used: the total number of deer observed, the number observed in the previous year, and the buck/doe ratio (Table 1).

2. Predation & Alternative Prey

   The availability of alternative prey ("buffer prey") to predators may reduce predation on fawns by means of a swamping or dilution effect. Black-tailed prairie dogs and small mammals are the most important buffer prey available to coyotes at RMA. Surveys of active prairie dog colonies at RMA yielded annual estimates of the occupied acreage. An unrelated study of small mammal communities associated with restored and unrestored grasslands at RMA provided data on the relative abundance of small mammals in some of the years of the deer surveys (Table 1).

3. Climate

   Climate data was obtained from the National Weather Service's Forecast Office at http://www.crh.noaa.gov/den/cli/climo.html which reports daily and monthly summaries from a station immediately adjacent to RMA at the former Denver-Stapleton International Airport. The specific data included are summarized in Table 1.

Table 1. Independent variables that were examined as potential influences on recruitment.

Variable Abbreviation	Description	Years for which data occurred
MD Total	Total number of mule deer observed	1995-2003
MD X-1	Total number of mule deer observed in the previous year	1996-2003
MD Buck/Doe	Mule deer bucks per 100 does	1995-2003
WT Total	Total number of white-tailed deer observed	1995-2003
WT X-1	Total number of while-tailed deer observed in the previous year	1996-2003
WT Buck/Doe	White-tailed deer bucks per 100 does	1995-2003
[Monthly} Temp. (dptr)	Mean monthly (January – July) temperature as a departure from the 50 year average.	1995-2003
[Monthly} Temp 32 Max	The number of days in each month (Jan – April) in which the temperature did not exceed 32 degrees F (0 degrees C)	1995-2003
[Monthly] Temp Max 90+	The number of days in each month (June - July) in which the temperature exceeded 90 degrees F (32 degrees C)	1995-2003
[Monthl] HDD (dptr)	Monthly (Jan – April) heating degree days as a departure from the 50 year average	1995-2003
[Monthly] CDD (dptr)	Monthly (May - July) cooling degree days as a departure from the 50 year average	1995-2003
[Monthly] Precip (dptr)	Monthly inches of precipitation as a departure from the 50 year average	1995-2003
Pdog (Acres)	Number of acres of active prairie dog colonies	1995-2003
Sm. Mam. Totals	Total capture from a separate small mammal study	1997, 1998, 1999, 2001, 2003

RESULTS

Density-Dependence

Examination of partial correlation coefficients for demographic variables suggest that mule deer recruitment (MD Fawn/Doe) was probably not influenced by any of the demographic factors we studied during the time period of this data set (Table 2). Partial correlation examines the influence of each variable after the effects of the other variables has been removed. There were no strongly negative coefficients related to fawn:doe ratios. Mule deer recruitment was positively correlated with the total number of deer observed (MD Total), an indicator of total population size.

Table 2. Partial Correlation Matrix for Mule Deer Demographic Variables

	MD Total	MD X-1	MD Buck/Doe
MD X-1	0.042		
MD Buck/Doe	-0.436	-0.260	
MD Fawn/Doe	0.576	0.141	-0.124

On the other hand, white-tailed deer recruitment (WT Fawn/Doe) was negatively related to all three demographic variables (Table 3) suggesting that recruitment may be density dependent. This may be the case if the relatively small acreage of white-tailed deer habitat; which at RMA is riparian woodland, is limiting. See conclusions section for further discussion of this possibility.

Table 3. Partial Correlation Matrix for White-tailed Deer Demographic Variables

	WT Total	WT X-1	WT Buck/Doe
WT X-1	-0.561		
WT Buck/Doe	-0.707	-0.608	
WT Fawn/Doe	-0.559	-0.786	-0.601

Density dependence can be further examined by performing Correlation Z-tests for significance of the influence of correlation coefficients. While no significant Z-scores were found, mule deer recruitment was again positively correlated with population size (Table 4) and white-tailed deer recruitment was negatively correlated with the previous year's population size (WT X-1, Table 5).

Table 4. Correlation Z-Tests for Mule Deer Demographic Variables

	Corr. Coeff.	n	Z-Value	P-Value
MD Total, MD X-1	0.439	7	0.941	0.3468
MD Total, MD Buck/Doe	-0.582	8	-1.489	0.1365
MD Total, MD Fawn/Doe	0.692	8	1.904	0.0569
MD X-1, MD Buck/Doe	-0.489	7	-1.07	0.2847
MD X-1, MD Fawn/Doe	0.439	7	0.942	0.346
MD Buck/Doe, MD Fawn/Doe	-0.256	9	-0.64	0.5219

Table 5. Correlation Z-Tests for White-tailed Deer Demographic Variables

	Corr. Coeff.	n	Z-Value	P-Value
WT Total, WT X-1	-0.105	7	-0.211	0.8332
WT Total, WT Buck/Doe	-0.255	8	-0.583	0.5602
WT Total, WT Fawn/Doe	-0.263	8	-0.602	0.5469
WT X-1, WT Buck/Doe	-0.175	7	-0.353	0.7239
WT X-1, WT Fawn/Doe	-0.644	7	-1.530	0.1260
WT Buck/Doe, WT Fawn/Doe	-0.255	9	-0.638	0.5234

2. Predation & Alternative Prey

Proximate evidence of predation is difficult to separate from more ultimate and general causes of mortality in fawns. A fawn that dies from exposure, malnutrition, or some other reason is likely to be scavenged by predators eventually. Therefore, a hypothesis that predation has resulted in the recent decline in deer recruitment at RMA can be examined in theory by correlations of recruitment with the availability of alternative prey such as black-tailed prairie dogs and other small mammals. While it was mentioned that coyote populations may have increased in recent years, no significant correlations were found between the availability of alternative prey and recruitment (Table 6).

Table 6. Correlation Z-Tests for Fawn/Doe Ratios and Alternative Prey Availability

	Corr. Coeff.	Count	Z-Value	P-Value
MD Fawn/Doe, Pdog (Acres)	-0.212	9	-0.528	0.5974
MD Fawn/Doe, Sm. Mam. Totals	-0.123	5	-0.175	0.8608
WT Fawn/Doe, Pdog (Acres)	-0.254	9	-0.636	0.5246
WT Fawn/Doe, Sm. Mam. Totals	-0.124	5	-0.177	0.8599

3. Climate

Similar correlation Z-tests were performed on all climate variables. Interestingly, significant negative correlations with recruitment were found for the same variable in both mule and white-tailed deer; that of the number of days in July when temperatures were above 90 degrees Fahrenheit (32 degrees C, Tables 7 and 8).

Table 7. Correlation Z-Tests for Climate Variables & Mule Deer Fawn/Doe Ratios

	Corr. Coeff.	n	Z-Value	P-Value
Jan Temp. (dptr)	-0.289	9	-0.728	0.4664
Jan Temp 32 Max	0.240	9	0.600	0.5487
Jan HDD (dptr)	0.155	9	0.382	0.7024
Jan Precip (dptr)	-0.366	9	-0.940	0.3472
Feb Temp. (dptr)	0.168	9	0.415	0.6784
Feb Temp 32 Max	-0.036	9	-0.088	0.9300
Feb HDD (dptr)	-0.120	9	-0.295	0.7678
Feb Precip (dptr)	-0.107	9	-0.262	0.7931
Mar Temp. (dptr)	0.268	9	0.673	0.5009
Mar Temp 32 Max	0.157	9	0.388	0.6982
Mar HDD (dptr)	-0.271	9	-0.682	0.4955

Mar Precip (dptr)	-0.233	9	-0.581	0.5610
Apr Temp. (dptr)	-0.428	9	-1.119	0.2631
Apr Temp 32 Max	0.206	9	0.511	0.6093
Apr HDD (dptr)	0.430	9	1.125	0.2605
Apr Precip (dptr)	-0.082	9	-0.201	0.8404
May Temp. (dptr)	0.175	9	0.434	0.6646
May CDD (dptr)	0.075	9	0.183	0.8544
May Precip (dptr)	0.086	9	0.211	0.8329
Jun Temp. (dptr)	-0.021	9	-0.051	0.9592
Jun Temp Max 90+	-0.414	9	-1.079	0.2807
Jun CDD (dptr)	-0.093	9	-0.228	0.8193
Jun Precip (dptr)	-0.127	9	-0.313	0.7541
Jul Temp. (dptr)	-0.490	9	-1.313	0.1891
Jul Temp Max 90+	-0.67	9	-1.984	0.0472
Jul CDD (dptr)	-0.517	9	-1.401	0.1614
Jul Precip (dptr)	0.275	9	0.692	0.4890

Table 8. Correlation Z-Tests for Climate Variables & White-Tailed Deer Fawn/Doe Ratios

	Corr. Coeff.	n	Z-Value	P-Value
Jan Temp. (dptr)	-0.512	9	-1.386	0.1659
Jan Temp 32 Max	0.438	9	1.151	0.2497
Jan HDD (dptr)	0.342	9	0.872	0.3832
Jan Precip (dptr)	-0.212	9	-0.528	0.5975
Feb Temp. (dptr)	0.081	9	0.198	0.8429
Feb Temp 32 Max	-0.069	9	-0.169	0.8655
Feb HDD (dptr)	-0.035	9	-0.085	0.9323
Feb Precip (dptr)	-0.253	9	-0.633	0.5270
Mar Temp. (dptr)	0.202	9	0.502	0.6159
Mar Temp 32 Max	0.220	9	0.549	0.5831
Mar HDD (dptr)	-0.201	9	-0.500	0.6171
Mar Precip (dptr)	-0.362	9	-0.929	0.3531
Apr Temp. (dptr)	-0.549	9	-1.512	0.1304
Apr Temp 32 Max	0.266	9	0.668	0.5041
Apr HDD (dptr)	0.540	9	1.479	0.1391
Apr Precip (dptr)	-0.110	9	-0.269	0.7877
May Temp. (dptr)	0.309	9	0.782	0.4339
May CDD (dptr)	0.081	9	0.200	0.8415
May Precip (dptr)	-0.156	9	-0.386	0.6995
Jun Temp. (dptr)	0.22	9	0.548	0.5835
Jun Temp Max 90+	-0.206	9	-0.512	0.6087
Jun CDD (dptr)	0.132	9	0.325	0.7450
Jun Precip (dptr)	-0.242	9	-0.605	0.5454
Jul Temp. (dptr)	-0.412	9	-1.073	0.2833
Jul Temp Max 90+	-0.696	9	-2.107	0.0351
Jul CDD (dptr)	-0.461	9	-1.220	0.2224
Jul Precip (dptr)	0.374	9	0.962	0.3359

CONCLUSIONS

Inference about what factor or factors have caused the recent declines in deer recruitment at RMA is certainly difficult to come by. From an examination of the available data presented herein, it may be possible to eliminate some factors while at the same time find support for others.

Density-dependent mechanisms that might influence recruitment have been found through several studies. Hobbs et.al. (1983) and Miller and Ozoga (1997) and references therein found evidence that overabundance that leads to habitat degradation may cause a reduction in recruitment through non-retention of the fetus by does, or by does that abandon fawns. We find no such correlation in the data from 1995-2003 at RMA. In fact, mule deer recruitment was positively (though not significantly) related to density.

There is some preliminary evidence that coyote populations have increased at RMA. While we cannot rule out additive mortality from predation as a possible factor that might explain low recruitment rates, there is reason to eliminate lack of alternative or "buffer" prey as a contributing mechanism. No significant relationships were observed between two measures of alternative prey abundance and recruitment for either deer species. Were there evidence to the contrary as in other studies (Hamlin et. al. 1984, Whittaker and Lindzey 1995, Ballard et. al. 2001, McNay and Voller 1995, Potvin et. al. 1981), it still may be unproductive to use predator control to remedy the situation. Until the ultimate rather than proximate causes of fawn mortality becomes known a decision on predator control should be delayed.

Of the possible contributing factors examined, climate, and specifically July warm temperatures appear to hold the greatest promise for further investigation. Many studies have examined the influence of severe winter weather on neonatal mortality, doe physiology, and subsequent recruitment (Bartmann and Bowden 1984, Verme 1968, Verme and Ozoga 1997, Wallmo and Gill 1971). Uncommon are studies that report the negative influence of warm, midsummer weather on recruitment. Yet both mule deer and white-tailed deer recruitment from 1995-2003 were significantly and negatively correlated to the number of days in July when temperatures were above 90 degrees. Heat stress, reduced vegetation cover from drought, or reduced nutritional content from drought-stressed vegetation may be the mechanisms involved. Although, further study is warranted, there may be little that can be done in terms of intervention or management if this is the case.

Our current research focus is to capture does (Mule and White-tail Deer), determine fertility rates[1] then radio-collar them and their fawns. Fawns will be followed through the first 9 months to 2 years to determine causes of mortality. Telemetry efforts, continued annual classification counts, and tracking of climate, predator, habitat, and alternative

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[1] In March, 2004, 25 Mule Deer does captured and examined by means of ultrasound were all pregnant with at least 1 fetus, and several had twins.

prey data will lead us to a better understanding of the factors that contribute to variation in deer demographics at RMA.

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