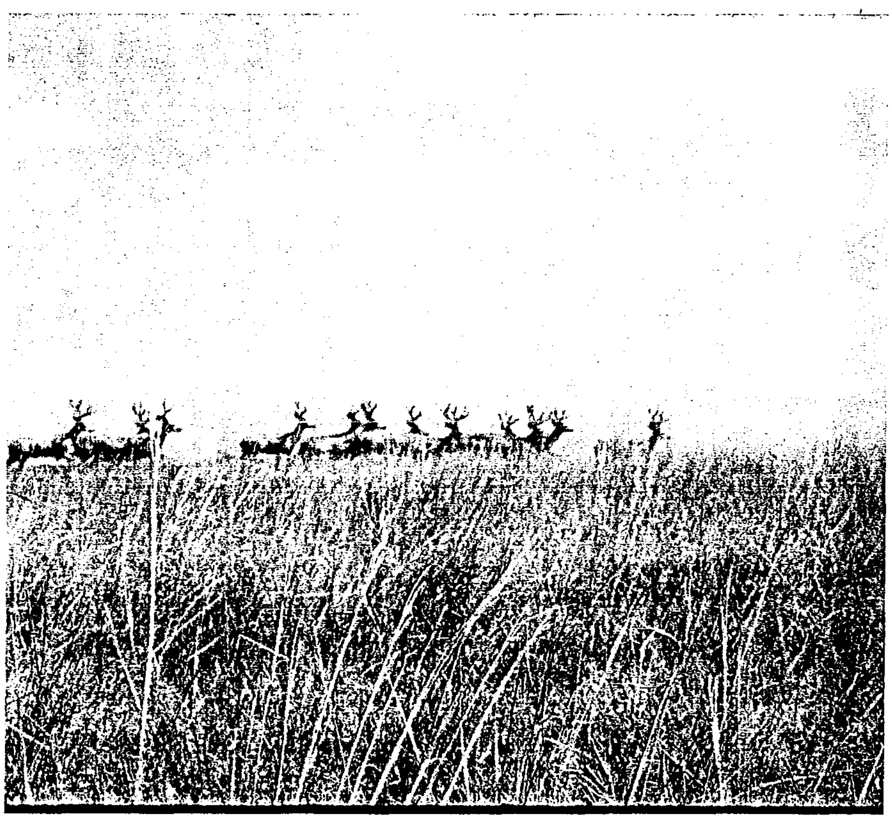
DEER CARRYING CAPACITY ON THE ROCKY MOUNTAIN ARSENAL NATIONAL WILDLIFE REFUGE BASED ON DRY MATTER INTAKE AND AVAILABLE DRY MATTER RESIDUE



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INTRODUCTION

In a landscape dominated by urban development, the Rocky Mountain Arsenal (RMA) is an especially important refuge for mule and white-tailed deer. RMA biologists estimate the current deer population exceeds 900 animals (approximately 250-300 white-tailed deer and 650-700 mule deer). The Comprehensive Management Plan for the RMA, completed in 1996, states that the Fish and Wildlife Service (Service) will manage deer populations between 325 and 550 total deer. These goals were generally based on habitat conditions from the early 1990's and deer research conducted on the refuge in the late 1980's (Matiatos pers. comm. 1999). A specific study evaluating carrying capacity of the habitats on the RMA had never been conducted. The current management approach is a conservative one that attempts to suppress deer populations and minimize habitat degradation by culling females. Culling may have suppressed populations somewhat, but the estimated total population is much higher than the current management goal. The large numerical span between the population estimate and the management goal indicates that habitats on the RMA may be able to support a much higher population of deer than was originally thought. Recognizing this need to evaluate the available habitats and create a more scientifically based method to estimate carrying capacity, the Service initiated this study.

OBJECTIVES

1) Use existing literature to determine the average dry matter intake of mule and white-tailed deer in similar habitats.

2) Use Whittaker (1995) to determine utilization of habitat on the RMA by mule and white-tailed deer.

3) Use the 1998 Rocky Mountain Arsenal vegetation classification map compiled by Morrison Knudsen Corporation, to determine the area of preferred habitat available to deer populations on the RMA

4) Determine forage biomass of the most important habitat types for deer species on the RMA.

5) Use the information collected in the first four objectives to estimate a population range for mule and white-tailed deer that will allow for maximum use of the preferred habitats on a sustained yield basis.

STUDY AREA

The RMA is located approximately 16 km northeast of downtown Denver, Colorado in Adams County (Figure 1). It was created in 1942 on approximately 20,000 acres of land that had been requisitioned by the United States Government. The RMA was created to produce chemical and incendiary munitions for use in World War II..

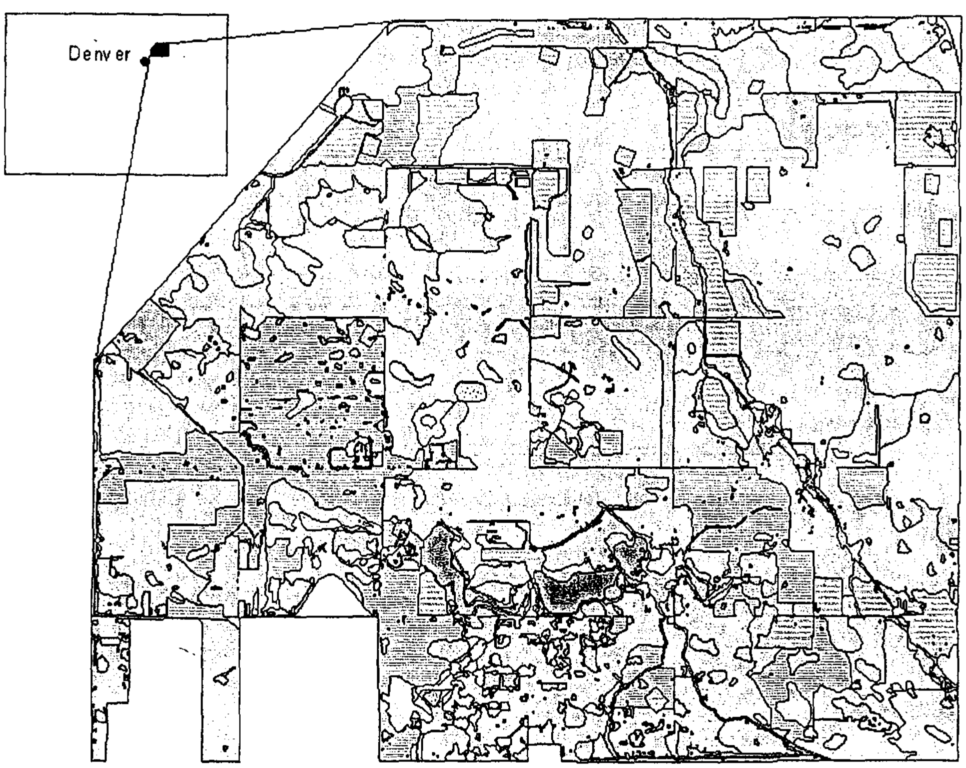
By the early 1980's, demilitarization and decontamination of the installation became a priority. In 1980, the Comprehensive Environmental Response, Compensation and Liability Act became federal law and by 1987, the Environmental Protection Agency declared the RMA a superfund cleanup site.

The substantial buffer area surrounding the chemical plants had remained largely undisturbed since the creation of the RMA. Thus, these lands became an important refuge for many species of wildlife that had been forced out of an increasingly urban landscape. On March 23, 1989, recognizing the ecological value of the site, the U.S. Army and the U.S. Fish and Wildlife Service entered into a cooperative agreement, for conservation and management of fish and wildlife resources on the RMA. Since that time, management of fish and wildlife resources has become a major priority, second only to continued cleanup of contaminated sites.

Prior to disturbance by man, the climax community for the RMA was short-grass prairie. However, because of human disturbance, the dominant vegetation now consists mainly of alien invaders. Although the 1998 RMA vegetation map lists 32 different classifications, five of those (weedy forbs, cheatgrass/weedy forbs, crested wheatgrass, crested wheatgrass/weedy forbs, and sand dropseed grasslands) comprise >75% of the total area (Morrison Knudsen Corporation 1998).

Elevation on the RMA ranges from 1564 m to 1625 m above sea level. The climate is semiarid with low humidity, light to moderate winds, and moderate annual precipitation averaging 32 cm.

Figure 1. Location of the RMA in Colorado.



METHODS, MODEL CALCULATIONS, AND JUSTIFICATION OF VARIABLES

We provide a simplistic forage production model that will estimate an annual population range or carrying capacity based on the dry matter intake of mule and white-tailed deer bucks, does and fawns. The range in carrying capacity was based on the 90% confidence interval of forage biomass estimates. There are many definitions for carrying capacity. Carrying capacity for this model was defined as the maximum stocking level possible year after year without inducing damage to vegetation or related resources (Holechek et al. 1998). Our carrying capacity estimates are driven by mean dry matter intake of deer, biomass production and remaining dry matter residue.

Dry Matter Intake

Dry matter intake values for mule deer of 1.7% and 2.9% of body weight (kg) per day were used for this model. These values are used by the Colorado Division of Wildlife Research Center, Fort Collins, Colorado (Baker, pers. comm. 2000) and were assumed to be the most realistic values for this geographic region. We had no information on the dry matter intake of white-tailed deer in similar habitats. However, because they utilize similar habitats and have similar forage preferences on the RMA (Whittaker 1995), we determined it acceptable for the goals of this model to use the same dry matter intake values for white-tailed deer as were used for mule deer. The mean dry matter intake value for RMA deer (TDI) was based on November 1999 buck:doe:fawn ratios for both species and was weighted to reflect the population ratio of mule deer to white-tailed deer. Bucks are male deer over 18 months of age, does are females over 18 months, and fawns are under 18 months. Weights and ratios used for calculations in this model are shown in Table 1. The TDI was determined by the following equations:

$$MDI = (\{x_{mdb}(d_{mdb})(r_{mdb})+x_{mdd}(d_{mdd})+x_{mdf}(d_{mdf})\}/\ 100\ /\ 3\ )\ 365$$

$$WTI = (\{x_{wtb}(d_{wtb})(r_{wtb})+x_{wtd}(d_{wtd})+x_{wtf}(d_{wtf})\}/\ 100\ /\ 3\ )\ 365$$

$$\mathbf{TDI} = MDI(p_{md}/p_{td}) + WTI(p_{wt}/p_{td})$$

Where:
MDI = mean mule deer dry matter intake
WTI = mean white-tailed deer dry matter intake
x = mean weight (kg)
d = % dry matter intake required for maintenance (kg/ day)
r = the ratio of either bucks or fawns to does
p = estimated RMA population

Subscripts =
mdb = mule deer bucks
mdd = mule deer does
mdf = mule deer fawns
wtb = white-tailed bucks
wtd = white-tailed does
wtf = white-tailed fawns
md = mule deer
wd = white-tailed deer
td = total RMA deer population

Table 1. Weights and population ratios of buck, doe and fawn mule deer and white-tailed deer used in the calculations of this model.

	mean weight (kg)	number of animals/doe		mean weight (kg)	number of animals/doe
mule deer buck	80	1.39	white-tailed buck	75	1.25
mule deer doe	60	1.0	white-tailed doe	55	1.0
mule deer fawn	35	0.35	white-tailed fawn	30	0.22

Determination of Habitat Types and Habitat Utilization

Because the RMA is entirely enclosed by an eight-foot fence, deer are limited to what habitat types and vegetative species are available for consumption. Therefore, diets of deer on the arsenal are somewhat different than what might occur in free ranging populations. For example, Hobbs et al. (1983), examining nutritional ecology of ungulates in Rocky Mountain National Park, stated that mule deer rely heavily on browse during the winter months while Whittaker (1995) indicated winter browse only comprised 8.8% of winter mule deer diet on the RMA. This observation is most likely a factor of the limited availability of shrubs on the RMA. Because the RMA is a unique situation, we used Whittaker (1995) exclusively to determine habitat utilization distributions (Figure 2) and diet preferences (forbs, grasses, and shrubs) for deer species on the RMA.

Using Geographic Information System (GIS) technology, the entire area of the RMA has been divided into 1607 polygons representing 40 habitat types (Morrison and Knudsen 1998). Maps from Whittaker (1995) were manually superimposed on GIS maps. All polygons within the habitat utilization distributions were considered available for deer occupancy.

Time and money constraints and the importance of maintaining a realistic sampling protocol for future biomass estimates required us to limit our sampling effort. The 40 habitat types were reorganized into 17 (Table 2). Reorganizing the habitats made them more comparable to maps from Whittaker (1995) as some designations had become more specific. For example, habitat designated as Native Perennial Grassland in 1995 became six different species specific grassland types in 1998. Six of the 17 habitat types (Weedy Forb, Cheatgrass/Weedy Forb, Crested Wheatgrass/Weedy Forb, Wetland Tree, Locust Thicket and Native Perennial Grassland) were selected as the most important habitat types for deer and used for biomass sampling (Figure 2). These six comprised 77% of the total RMA area, 79% of the mule deer and 85% of the white-tailed deer habitat utilization distributions. Thus, the six-selected habitat types provide a relatively complete picture of the actual forage available for deer consumption in areas most preferred by deer populations on the RMA.

Table 2. Reorganization of habitat types for use in this model.

1998 habitat type designation	New habitat type designation for this model
weedy forb	weedy forb
cheatgrass/weedy forb	cheatgrass/weedy forb
native perennial, blue grama, needle-and-thread, sand dropseed grassland, western wheatgrass, red three-awn, and foxtail barley grasslands, and inland saltgrass	native perennial grassland
Crested wheatgrass stands, crested wheatgrass	crested wheatgrass
crested wheatgrass/weedy forbs	crested wheatgrass/weedy forbs
shrublands/succulents, rubber rabbitbrush, sand sagebrush, yucca stands, cactus stands, shrub thickets, shrub windbreaks	shrublands
locust thicket	locust thicket
wetlands, cattail ribbons/marshes, bottomland meadows, weedy bottomlands, channel vegetation, cottonwood/willow gallery, coyote willow thickets, created wetlands	wetland/trees
tree groves	tree groves
lawns	lawns
seeded areas, seeded crested wheatgrass, seeded native perennial grassland	reseeded areas
cereal rye	cereal rye
cobble soil vegetation	cobble soil vegetation
alfalfa/sweetclover	alfalfa/sweetclover
bare ground	bare ground
unclassified	unclassified
water	water

Biomass Estimation

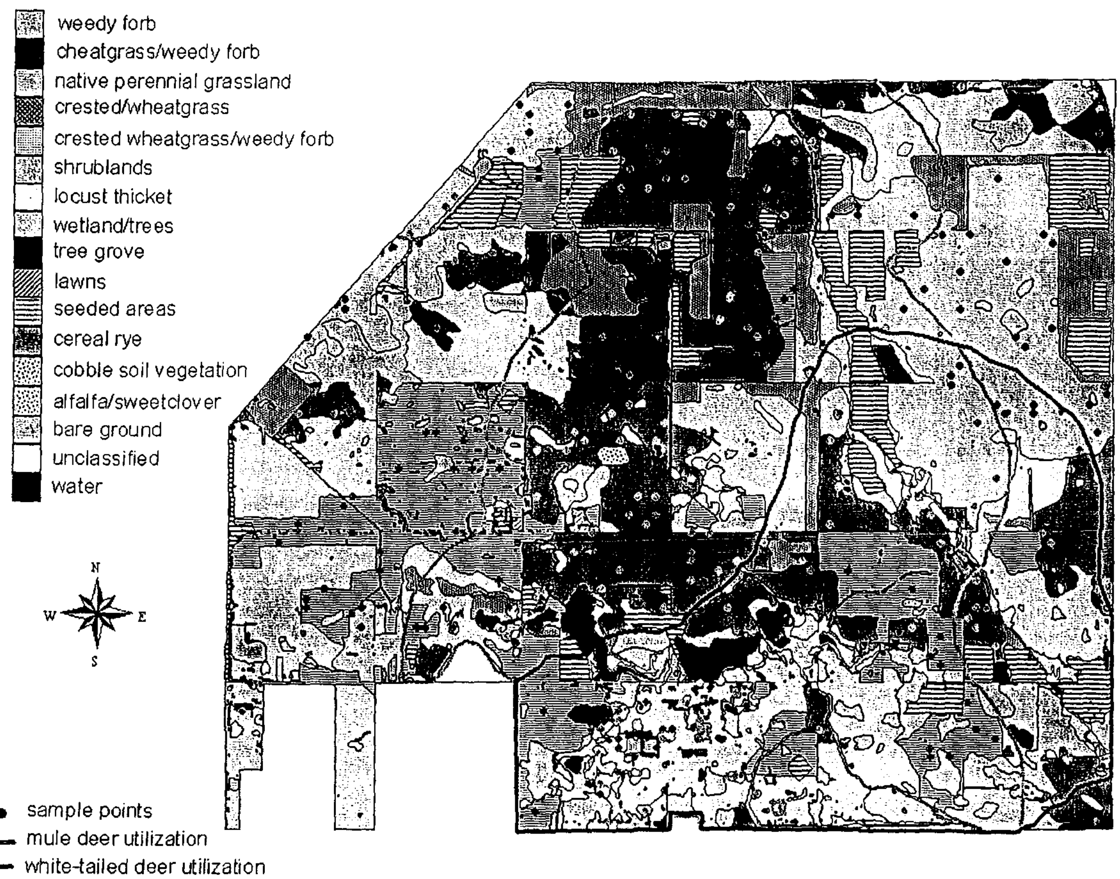
We were interested in determining the biomass of grasses and forbs during the fall (September 1-November 30) when energy content and forage quality on the RMA were assumed to be at their lowest levels. Thus, vegetative sampling was conducted between October 15th and November 30th 1999. A grid with points placed at 100m intervals was created in ARC INFO and superimposed on the GIS map of the RMA. Microsoft Excel (Berk and Cary 1995) was then used to randomly select a specified number of sample points in each habitat type (Figure 2). The resulting Universal Transverse Mercator (UTM) coordinates for each point allowed the sampler to easily locate the sample points on the ground using a hand held GPS unit. Randomly selected 0.25 m^2 quadrants located in the six habitat types were used to estimate forage biomass. After using grass clippers to cut all vegetative material within the quadrant to a height of 1 inch, it was sorted into either "grass" or "forb" categories, placed in brown paper bags and labeled. In the lab, the forb samples were further separated by species. All samples were then dried at 60 C for 48 hours and weighed to obtain a 100% dry matter weight. Fifteen vegetative samples in each vegetative type were collected 2-weeks prior to the initiation of the sampling used for the model. These "pilot study" samples were used to derive a variance and a mean for estimating the required minimum sample size with the equation:

$$N_{min} = Z^2 S^2 / (d \text{ mean})^2$$

where N_{min} equals the minimum number of quadrants required for an adequate sample based on the statistics calculated previously (s^2, mean) and where z is a t-value for a desired level of probability at n = infinity and d equals the % error allowable.

To keep vegetative measurements comparable from year to year, it is important to sample areas in close proximity to the previous year's measurements. All quadrants sampled this fall had their UTM coordinates recorded using a hand held, Army issued GPS unit that was accurate to < 6 m. Future samplers using the same or comparable GPS unit should be able to get reasonably close (<6m) to the initial quadrant. This should be in close enough proximity to avoid sampling an area that is not comparable, yet sill allow the sampler to avoid clipping the same quadrant.

Figure 2. Map of the RMA showing habitat types, vegetative sample points and habitat utilization distributions for mule and white-tailed deer.



Utilization Factor

Utilization has been defined by The Society of Range Management (1989) as the percentage of the current year's herbage production consumed or destroyed by herbivores. Decisions concerning utilization rate and carrying capacity on continuously grazed systems are generally made in the fall of the year. This allows the carrying capacity estimate to be adjusted so a minimum residue of dry matter remains (Holechek et al. 1998). The idea being that there is a certain minimum level of dry matter that should always be present on a particular range to maintain the soil, forage plant vigor, wildlife diet quality and wildlife habitat (Holechek et al. 1998). A lack of vegetation residue can result in soil erosion (McCalla et al. 1984) and can be harmful for wildlife species. The level of dry matter residue remaining is directly related to the utilization rate or the percentage of plant material removed from the range. The utilization factor is simply utilization rate divided by 100. For example, a utilization rate of 50% would give a utilization factor of 0.5. Utilization rate guidelines for different range types were compiled by Holechek (1988) based on existing research. They recommend a 40-50% utilization rate for moderate grazing of short-grass prairie regions averaging 25 - 40 cm precipitation annually. We used a utilization rate of 35% for this model, which corresponds to a use factor of 0.35. We used a more conservative utilization rate rather than the recommended level of 40% - 50% for the following reasons: First, although the RMA was historically a short-grass prairie ecosystem, very few sites exist that have not be partially or totally changed by human activities and the majority of the RMA vegetation is in early or mid-seral successional stages with much of the vegetation consisting of increasers and invaders. A utilization rate of 35% is more appropriate for our model because it may help speed recovery of the ecosystem to a late seral stage, where as a utilization rate of 40 - 50% would remove a greater percentage of the plant foliage and possibly slow down or inhibit recovery. Secondly, a more conservative utilization rate will insure that cover and forage availability for other wildlife and invertebrate species remains high. Finally, since our biomass estimates are of grazed habitats, they probably under-represent biomass that would be present on an ungrazed system. Our more conservative utilization factor will help account for the difference between grazed and ungrazed biomass and provide a "safety net" that will help avoid overgrazing of the vegetation and subsequent damage to the ecosystem. For example, if our biomass estimate is of a plot that has had 10% of the dry matter residue already removed by grazing and we allow for 35% additional removal, the actual utilization of that plot was 45%. Thus, the lower utilization factor allows for up to 15% removal of dry matter residue by grazers prior to sampling, while still maintaining a utilization rate under 50%.

Forage Preference

Forage preference was determined using seasonal (September 1 - November 30) fecal analysis results from Whittaker (1995). Forb species comprised the majority of fall mule (73%) and white-tailed (89%) deer diets. Grass comprised only 11% and 8% of mule and white-tailed deer diets, respectively. Shrubs comprised the remainder of the diet. To account for the preference of forbs over grasses in the model calculations we weighted the biomass estimates with the simple calculation:

%forbs/1 = %grass/w

The resulting proportion of grass species in the diet (w) when % forbs were set equal to one gave us our weighted value for grass (w = 0.14 for total deer, w = 0.16 for mule deer and w = 0.09 for white-tailed deer).

The Spreadsheet

The spreadsheet was created in a Microsoft Excel (Berk and Carey 1995). It allows the user to easily manipulate different variables that directly effect the population range estimate. These include the use factor, mean dry matter intake (which is determined by buck:doe:fawn ratios for mule and white-tailed deer and by mean weight of bucks, does, and fawns),the mean and 90% confidence interval for biomass estimates of forbs and grasses for each habitat type, habitat utilization area and the area of a particular habitat type. To manipulate the spreadsheet it must first be un-protected. The password is given in Appendix 1.

Model Calculations

Low and high carrying capacity estimates for deer populations for each of the six habitat types were computed for total deer, mule deer, and white-tailed deer using the following equations:

$$TD^h_{min} = \{(x_f - CI_f)4 / 1000\,(th)\,(u) / i_{td}\} + \{(x_g - CI_g)(w_{td})(4) / 1000\,(th)\,(u) / i_{td}\}$$

$$TD^h_{max} = \{(x_f + CI_f)4 / 1000\,(th)\,(u) / i_{td}\} + \{(x_g + CI_g)(w_{td})(4) / 1000\,(th)\,(u) / i_{td}\}$$

$$MD^h_{min} = \{(x_f - CI_f)4 / 1000\,(mh)\,(u) / i_{md}\} + \{(x_g - CI_g)(w_{md})(4) / 1000\,(mh)\,(u) / i_{md}\}$$

$$MD^h_{max} = \{(x_f + CI_f)4 / 1000\,(mh)\,(u) / i_{md}\} + \{(x_g + CI_g)(w_{md})(4) / 1000\,(mh)\,(u) / i_{md}\}$$

$$WT^h_{min} = \{(x_f - CI_f)4 / 1000\,(wh)\,(u) / i_{wt}\} + \{(x_g - CI_g)(w_{wt})(4) / 1000\,(wh)\,(u) / i_{wt}\}$$

$$WT^h_{max} = \{(x_f + CI_f)4 / 1000\,(wh)\,(u) / i_{wt}\} + \{(x_g + CI_g)(w_{wt})(4) / 1000\,(wh)\,(u) / i_{wt}\}$$

The breakdown of carrying capacity estimates for mule and white-tailed deer within the TD estimate was computed with the equations:

$$TDWT^h_{min} = \{(x_f - CI_f)4 / 1000\,(wo)\,(u) / i_{wt}\} + \{(x_g - CI_g)(w_{wt})(4) / 1000\,(wo)\,(u) / i_{wt}\} + \{(x_f - CI_f)4 / 1000\,(o)\,(u)\,(pr) / i_{wt}\} + \{(x_g - CI_g)(w_{wt})(4) / 1000\,(o)\,(u)\,(pr) / i_{wt}\}$$

$$TDWT^h_{max} = \{(x_f + CI_f)4 / 1000\,(wo)\,(u) / i_{wt}\} + \{(x_g + CI_g)(w_{wt})(4) / 1000\,(wo)\,(u) / i_{wt}\} + \{(x_f + CI_f)4 / 1000\,(o)\,(u)\,(pr) / i_{wt}\} + \{(x_g + CI_g)(w_{wt})(4) / 1000\,(o)\,(u)\,(pr) / i_{wt}\}$$

$$TDMD^h_{min} = TD^h_{min} - TDWT^h_{min}$$

$$TDMD^h_{max} = TD^h_{max} - TDWT^h_{max}$$

where:

- TD^h_{min} = the low total deer population estimate that a particular habitat type (h) can support annually.
- TD^h_{max} = the high total deer population estimate that a particular habitat type (h) can support annually.
- MD^h_{min} = the low mule deer population estimate that a particular habitat type (h) can support annually.
- MD^h_{max} = the high mule deer population estimate that a particular habitat type (h) can support annually.
- WT^h_{min} = the low white-tailed deer population estimate that a particular habitat type (h) can support annually.
- WT^h_{max} = the high white-tailed deer population estimate that a particular habitat type (h) can support annually.

$TDWT^h_{min}$ = The low carrying capacity estimate for white-tailed deer within the TD estimate for each of the six-sampled habitat types (h)

$TDWT^h_{max}$ = The high carrying capacity estimate for white-tailed deer within the TD estimate for each of the six-sampled habitat types (h)

$TDMD^h_{min}$ = The low carrying capacity estimate for mule deer within the TD estimate for each of the six-sampled habitat types (h)

$TDMD^h_{max}$ = The high carrying capacity estimate for mule deer within the TD estimate for each of the six-sampled habitat types (h)

x = the mean oven dried weight of forbs or grasses collected per $1/4m^2$ quadrant.
CI = the 90% confidence interval of the mean oven dried weight of forbs or grasses collected per $1/4m^2$ quadrant.
u = the utilization factor = (0.35)
i = the mean dry matter intake value per year (kg)
w = the weighted value for grasses based on fecal analysis
pr = the population ratio of white-tailed deer to total deer
th = the area (m^2) of the particular habitat type (h) included in RMA total for both mule deer and white-tailed deer habitat utilization distributions
mh = the area (m^2) of the particular habitat type (h) included in RMA total mule deer habitat utilization distributions
wh = the area (m^2) of the particular habitat type (h) included in RMA total white-tailed deer habitat utilization distributions
o = the area (m^2) of the particular habitat type (h) included in RMA mule deer and white-tailed deer overlapping habitat utilization distributions
wo = the area (m^2) of the particular habitat type (h) included in RMA white-tailed deer only habitat utilization distributions

Subscripts =
f = forbs
g = grasses
td = total deer
md = mule deer
wt = white-tailed deer

To derive an overall population range for total deer (TD), mule deer (MD), white-tailed deer (WT), white-tailed deer within total deer (TDWT), and mule deer within total deer (TDMD), we simply summed all low estimates and all high estimates from each habitat type for TD, MD, WT, TDWT, and TDMD.

RESULTS AND DISCUSSION

Based on our model calculations, forage biomass available on the six-sampled habitat types can support 1447-2836 mule deer or 1559-3125 white-tailed deer on a continuous grazing system if only one species is present. When estimating carrying capacity based on habitat utilization areas and factoring in competition between species, the RMA can support 1013-1923 total deer (767-1437 mule deer and 246-486 white-tailed deer). These estimates are based on November 1999 buck:doe:fawn ratios and population estimates.

White-tailed deer populations on the RMA are probably limited by human disturbance and activity rather than habitat availability because they need to be close to cover (Whittaker 1995). Thus managing white-tailed deer based on a carrying capacity estimate that included the entire area of the RMA as inhabitable by white-tailed deer would seriously misrepresent the true habitat available and lead to overpopulation of current habitat utilization areas. Mule deer on the other hand are not as disturbed by human activity on the RMA, and are often observed feeding on the front lawn of the main office building. Mule deer selected habitats based primarily on forage availability and secondarily for cover (Whittaker 1995). Because mule deer do not seem to be limited by cover, adding the area of habitat types with a significant forb component (WF, CWF, CWWF and NPG) that exist outside of the habitat utilization boundaries into the calculation of carrying capacity seems reasonable. However, doing so would probably increase grazing pressure on habitat utilization areas. Because we feel it is important to maintain the 35% utilization rate on these preferred sites and limit use of the fragile wetland tree habitat type, we recommend using the carrying capacity estimate restricted by habitat utilization areas for both white-tailed and mule deer.

Obviously this model is not to be used as the only means to assess deer populations on the RMA. It is intended to be used as an additional tool to help assess current deer management practices, and when combined with other knowledge of the habitat and behavior of RMA deer, will provide important management information for biologists. For this model to be most effective and accurate, biomass estimates will need to be continuously updated to account for changes in annual production. Yearly estimates would be the most beneficial, however because of the fairly wide span between the high and low population estimates it is probably not required. We suggest that a reassessment of production initiated every 2-3 years would provide the best balance between information gained pertaining to changes in management strategies and expense. The current model is based on biomass production at one point in time and does not take into account the wide variability in biomass production that can occur from year to year. Therefore, we suggest biologist use the low carrying capacity estimate for management decisions, until additional data is collected. As additional data is collected, the predictive power and accuracy of this model will increase. When a more accurate picture of biomass production trends on the RMA is achieved, biologist might then try to manage carrying capacity based on the average biomass production estimates across several years of data collection. While the recommended strategy will often leave available habitat underutilized, it will reduce the intensity of large-scale die-offs when severe weather (drought or cold) occurs (Strickland et al. 1994).

Reclamation of disturbed areas to native prairie is an important management goal that is currently affecting major portions of the RMA. In the future this will have a major impact on the capability of this model to estimate carrying capacities. To account for the change in habitat type and vegetative composition, RMA biologists will eventually need to sample these areas as a separate habitat type and include them in the model. Obviously area gained by one habitat type is area lost by another, so these changes will need to be updated as well. If the current reclamation objective of returning the RMA to native vegetation is accomplished, it will reduce carrying capacity estimates for both mule and white-tailed deer, assuming forb biomass is reduced.

Changes in human activity on the RMA may also effect the habitat utilization distributions of deer, especially white-tailed deer. Current cleanup activities on the RMA have greatly increased human presence and activity. After these major cleanup projects are completed, some habitats that are considered unavailable at this time may become usable. Thus, in the future biologists may want to reassess the habitat utilization distribution boundaries and adjust the available area of habitat used in model calculations accordingly.

CONCLUSIONS

Current deer populations of the RMA are near carrying capacities estimated by this model. We recommend managers use this model as an additional tool to help decide the biological carrying capacity of deer populations on the RMA. It is not intended to serve as a sole predictor of deer carrying capacity. The predictive power of this model will increase as more data is collected and biologists gain a greater understanding of biomass production on the RMA. We suggest using the lower carrying capacity estimate when managing deer populations until this additional data is collected. Although this strategy will often cause an under-utilization of most habitats, it will also help avoid over-grazing on drought years, which will reduce damage to soil and vegetative components. As habitats are altered on the RMA, the available habitats and % composition of forbs and grasses will need to be adjusted accordingly. Area of habitat utilization distributions may also need to be adjusted as human activity levels change due to completion of current major cleanup activities.

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