

FINAL REPORT

POPULATION AND ECOLOGICAL CHARACTERISTICS
OF WHITE-TAILED DEER ON CATOCTIN MOUNTAIN PARK

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INTRODUCTION AND OBJECTIVES

The white-tailed deer (Odocoileus virginianus) is a very adaptive species with a relatively high reproductive rate. As such, it has become a very popular game species in most areas of North America. Because of the absence of natural predators in many areas of its range, deer populations are most commonly controlled through regulated hunting. Deer populations must be kept in balance with their habitat's carrying capacity to prevent overpopulation and overbrowsing, which can cause serious impacts on native habitats and vegetation communities (Halls 1978, Hesselton and Hesselton 1982, Halls 1984).

While regulated hunting will effectively control deer populations in most situations, it has not been a permissible population management tool in certain areas. In national parks, state parks, and military reservations deer hunting often is not allowed, and overpopulation has become a very serious resource management problem. Alternative methods of controlling deer populations may be needed in these areas where deer hunting is not permitted.

The National Park Service (NPS) is responsible for administration and management of Catoctin Mountain Park (CATO) in Maryland. Deer hunting is not permitted on CATO, and the NPS is concerned that the uncontrolled deer herd on CATO may be adversely affecting the current and future forest ecosystem in the Park. Prior to instituting any type of deer population management efforts, however, the NPS must have detailed evaluations of population and ecological characteristics of deer on CATO. This project was conducted to determine baseline population and ecological characteristics for the CATO deer herd to provide the basis for management recommendations. Specific objectives were:

1. To examine movements of deer on CATO during winter, spring, summer, and fall seasons of 1988-1989.

2. To estimate population numbers, age ratios, sex ratios, and doe:fawn ratios for the CATO deer herd during 1988-1989.
3. To evaluate deer herd condition and health on CATO using physiological indicators collected on site during 1988-1989.
4. To evaluate general habitat characteristics and the relationship of the deer herd to its' carrying capacity (using physiological indicators) on CATO during 1988-1989.
5. To estimate over-winter mortality of radio-collared fawns on CATO during the winter of 1988-1989.
6. To recommend management alternatives for NPS natural resources personnel to consider in their efforts to monitor, evaluate, and control (if necessary) the CATO deer herd.

ACKNOWLEDGEMENTS

Field work on this project represented a cooperative effort. Personnel from the NPS and the University of Georgia, as well as individuals from CATO's volunteer organization (Catoctin Area Mountain Park Environmental Resource; CAMPER) participated in data collection. In particular, Dr. John Hadidian, Mr. Dennis Carruth, Mr. William Smith, Ms. Dianne Ingram, Mr. George Davis, Mr. Dan Roddy, and Mr. Roger Steintl helped provide continuity in data collection. Dr. John Hadidian provided valuable review and comment on the draft version of this final report.

STUDY AREA

CATO is located in western Maryland in the Appalachian Mountains Region, which is characterized by northern hardwood forest habitat types (Shrauder 1984).

Most deer populations in this region generally are characterized as being in healthy condition with relatively high productivity rates (Shrauder 1984). However, isolated areas of low soil fertility and accompanying low forage quality occur in this region and account for decreased range carrying capacity (Shrauder 1984). Major vegetation types on CATO include mixed forests dominated by chestnut oak (Quercus prinus), American beech (Fagus grandifolia), red maple (Acer rubrum), white ash (Fraxinus americana), pitch pine (Pinus rigida), Canada hemlock (Tsuga canadensis), North American tuliptree (Liriodendron tulipifera), American sycamore (Plantanus occidentalis), blackgum tupelo (Nyssa sylvatica), and flowering dogwood (Cornus florida). A more detailed description of vegetation communities present on CATO was presented by Hickey (1975).

METHODS

Deer Movements

Efforts to capture adult does for attachment of radio transmitter collars (164-166 MHz) occurred from December 1987 through February 1988 using immobilization drugs (xylazine hydrochloride and ketamine hydrochloride; Mech et al. 1985) and clover traps (Clover 1956). These efforts were detailed in the April 1988 progress report (Appendix I). Additional field work was conducted in November 1988 and January 1989 to capture and radio-collar does and fawns using immobilization drugs and a corral/drive-net trap (Warren and Ford 1989). Refer to the attached progress reports (Appendices I and II) for details on deer capture efforts.

Deer were located by triangulation (Cochran 1980). The detailed radiotelemetry survey route and schedule were presented in the April 1988 progress report (Appendix I). Most telemetry monitoring was conducted about one

hour after sunrise and one hour before sunset; nocturnal locations and movements were not obtained. From December 1988 through April 1989, radio transmitters (equipped with mortality sensors) of fawns were monitored at least every other day by NPS personnel and CAMPER volunteers to determine the exact day of fawn mortality.

Computer program TELEM88 (Coleman and Jones 1986) was used to convert compass bearing data collected from known reference stations into X-Y coordinates for each location based on the Universal Transverse Mercator (UTM) system. Only bearings taken within a 20-minute time period and that resulted in a triangulation angle of intersection greater than 30 degrees were used in the analysis. The resulting X-Y coordinates were used to calculate home range by the minimum convex polygon (MCP) method using 95% of the observations closest to the arithmetic center of the range. Computer program HOMERANGE (Ackerman et al. 1988) was used on an IBM PC equipped with a math coprocessor to calculate home range and distance moved between successive locations. The Statistical Analysis System (SAS; Joyner 1985) was used to sort monthly movement data into seasons (winter: Jan-Mar; spring: Apr-Jun; summer: Jul-Sep; fall: Oct-Dec). Significant differences among seasons were determined using analysis of variance followed by the Duncan's Multiple Range Procedure run on PROC GLM of SAS. Statistical significance was indicated by $P < 0.05$. A Hewlett-Packard Plotter was used to plot home range contours relative to the boundary of CATO to depict the amount of movement by deer off of NPS property.

Deer Population Numbers

Deer population numbers were estimated using pellet group counts (Eberhardt and van Etten 1956, Rogers 1987) conducted in September and October 1988, and by helicopter counts conducted by NPS personnel in March 1989. Details on the

pellet group count survey method were presented in the January 1989 progress report (Appendix II). A spotlight survey technique (McCullough 1982, Wood et al. 1985) was conducted in June, August, and September 1988 (refer to Appendix II for details) to estimate sex ratios (Giles 1978:52) and fawn/doe ratios (Hayne 1984).

Deer Condition and Health Indicators

Samples for evaluating physiological indicators of deer condition and health were obtained from three sources: deer killed on roads in and immediately around CATO, deer that died during capture operations associated with the Deer Movements Study, and from a sample of five adult deer collected by the Southeastern Cooperative Wildlife Disease Study (SCWDS), College of Veterinary Medicine, University of Georgia (refer to Appendix II for details). NPS personnel at CATO assisted in the collection and necropsy of road-killed deer. A detailed necropsy protocol was presented in the January 1989 progress report (Appendix II). Deer condition and health were estimated using age-specific body weights, the kidney fat index (KFI; Riney 1955), the abomasal parasite count (APC) technique (Eve and Kellogg 1977), crude protein levels of rumen contents (Warren and Krysl 1983), and evaluations of ovulation and reproductive rates in adult does (Cheatum 1949).

Deer condition indicators were analyzed statistically to determine the significance of seasonal variations. Adult deer were grouped according to season (winter, spring, summer, fall) collected, and tested by analysis of variance and Duncan's Multiple Range Procedure at $P < 0.05$ (PROC GLM on SAS; Joyner 1985). Deer condition and health indicators were used collectively to interpret the relationship of the CATO deer herd to its habitat's carrying capacity (Eve 1981, Davidson et al. 1982).

Habitat Evaluations

Habitats on CATO were evaluated using general field survey techniques, such as ocular estimates of browse species and browse utilization (Shafer 1965) and general field observations of plants (Harlow 1984).

RESULTS AND DISCUSSION

Deer Movements

Eight does were radio-collared and monitored for the movement study (see Appendix II for details); however, radio-telemetry data for statistical analysis of seasonal differences in movement rates were available from only five adult does (Table 1). A substantial amount of individual variation occurred in the movement patterns of these five does. In particular, Doe 164.470 demonstrated much greater movement in spring than the other does, which obviously skewed the mean movement distances for all does during that season (Table 1). When analyzed to evaluate seasonal differences in movements, does tended to move more in winter and spring than in summer and fall, but these differences were not statistically significant (Table 1). Storm et al. (1989) evaluated movement rates of female deer on Gettysburg National Military Park (GNMP) and Eisenhower National Historic Site (ENHS) in Pennsylvania and found significant differences among seasons, with deer moving most during winter and least during spring. They attributed the more active movement patterns of does in winter to the influence of the breeding season, hunting season, and relative scarcity of crops; less active movement patterns of does in spring were attributed to restricted activity associated with the fawning season.

Annual home ranges for all does relative to CATO's boundary are presented in Figure 1. The does with smaller home ranges tended to confine their movements

Table 1. Seasonal mean distances moved (meters) between successive telmetric observations for individual adult does on Catoctin Mountain Park, 1988-1989.

Deer Frequency Number	Season								Annual Mean
	Fall		Winter		Spring		Summer		
	n ^a	$\bar{x}$	n ^a	$\bar{x}$	n ^a	$\bar{x}$	n ^a	$\bar{x}$	
164.180	66	496	66	590	44	624	53	492	549
164.229 ^b	21	1,053	--	--	--	--	--	--	--
164.230 ^c	--	--	23	599	--	--	--	--	--
164.290	55	768	32	878	20	742	28	731	783
164.470	50	740	35	898	26	1,520	21	859	945
164.513	50	683	44	871	36	706	59	551	684
164.740 ^d	16	1,366	--	--	--	--	--	--	--
166.813	68	779	37	658	32	470	53	700	681
Seasonal $\bar{x}$	5 ^e	693	5 ^e	779	5 ^e	812	5 ^e	667	
S. D. ^f	116		144		409		147		

^aNumber of locations/deer/season.

^bAdult doe monitored November and December 1988; killed in December 1988; not included in statistical analysis.

^cAdult doe monitored February and March 1989; not included in statistical analysis.

^dAdult doe monitored only December 1988; not included in statistical analysis.

^eNumber of deer upon which seasonal mean and statistical test based.

^fStandard deviation.

HOME RANGES (95% MCP) OF ALL DOES

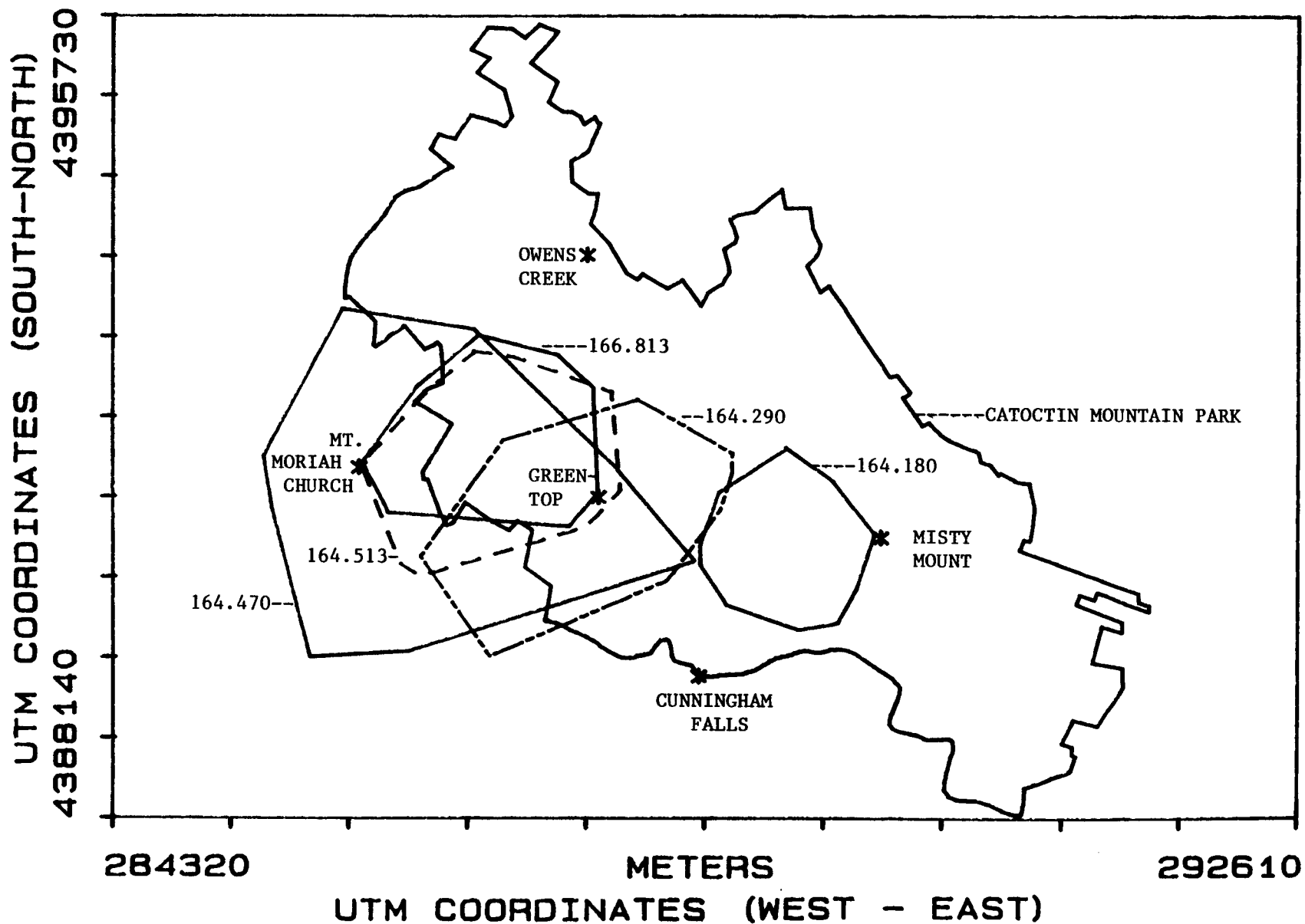


Figure 1. Annual home ranges of five radio-collared does in relation to the park boundary, Catoctin Mountain Park, Maryland, 1988-1989.

within CATO's boundary, whereas the does with larger home ranges tended to more likely move off of the Park (Fig. 1). Most of the does analyzed (four out of five) had home ranges that included areas off of the Park (Fig. 1). Most commonly, these areas were agricultural fields adjacent to CATO. Storm et al. (1989) also found radio-collared deer frequently moved across park boundaries onto private land in Pennsylvania. In their study, 18-33% of their radio locations of deer were on private land.

Figures 2-7 depict seasonal changes in home ranges for the individual does. For the does examined in this study, there did not appear to be a particular season during which they were most likely to use habitats located off of the Park (Figs. 2-7). For deer, distinctly different seasonal home ranges usually reflect severe winter weather characteristic of more northern habitats (Verme 1973). Although, deer movements can vary among seasons in response to variations in food availability (Marchinton and Jeter 1967, Byford 1970), with greater movements or shifts in home range locations in response to changes in food availability.

Seven fawns were radio collared and monitored to determine over-winter fawn mortality (see Appendix II for details). Of the seven fawns radio-collared, one was confirmed to have died during the Winter of 1988-89. This fawn was relatively small and emaciated at necropsy, and likely died as a result of malnutrition. Mortality rates during this winter probably were lower than normal, because over-winter temperatures were generally higher than normal and snowfall accumulations were generally less than normal (R. Steintl, pers. commun.).

Deer Population Numbers

Population estimates derived from pellet group counts were detailed in the January 1989 progress report (Appendix II). Considering the current knowledge

SEASONAL HOME RANGES (95% MCP) OF DOE 164.180

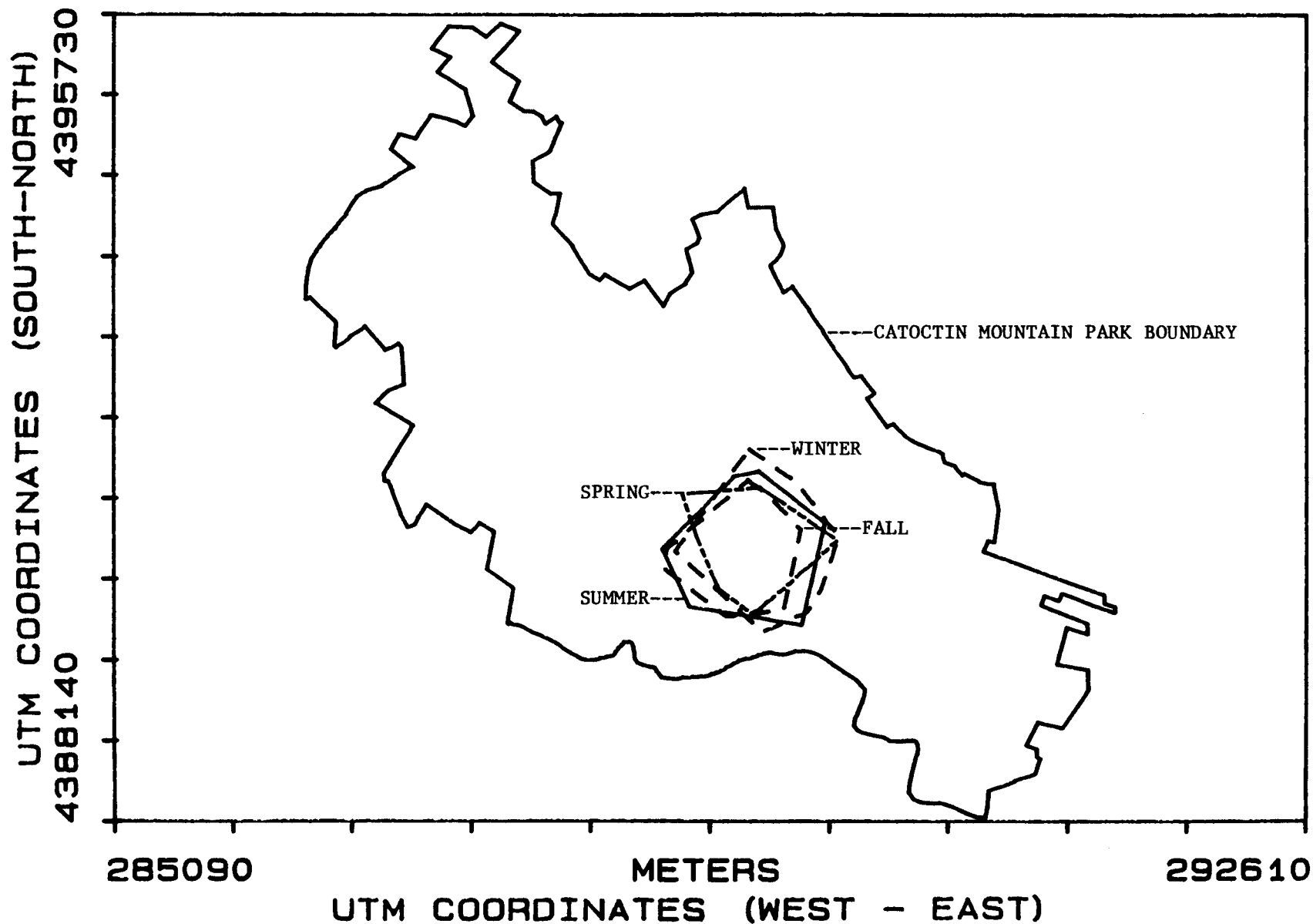


Figure 2. Seasonal home range plots relative to the park boundary for Doe No. 164.180, Catoclin Mountain Park, Maryland, 1988-1989.

SEASONAL HOME RANGES (95%MCP) OF DOE 164.290

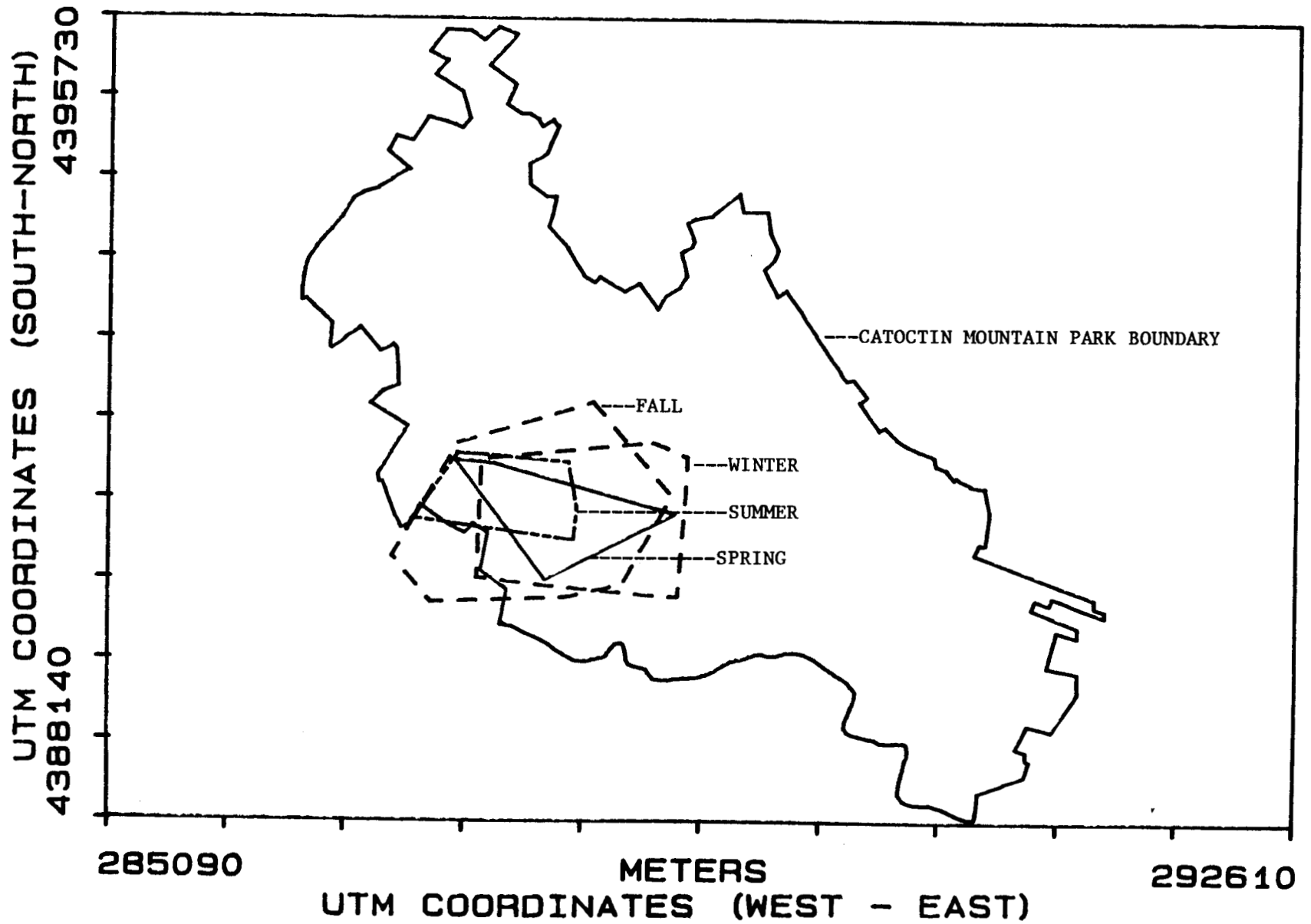


Figure 3. Seasonal home range plots relative to the park boundary for Doe No. 164.290, Catoclin Mountain Park, Maryland, 1988-1989.

SEASONAL HOME RANGES (95% MCP) OF DOE 164.470

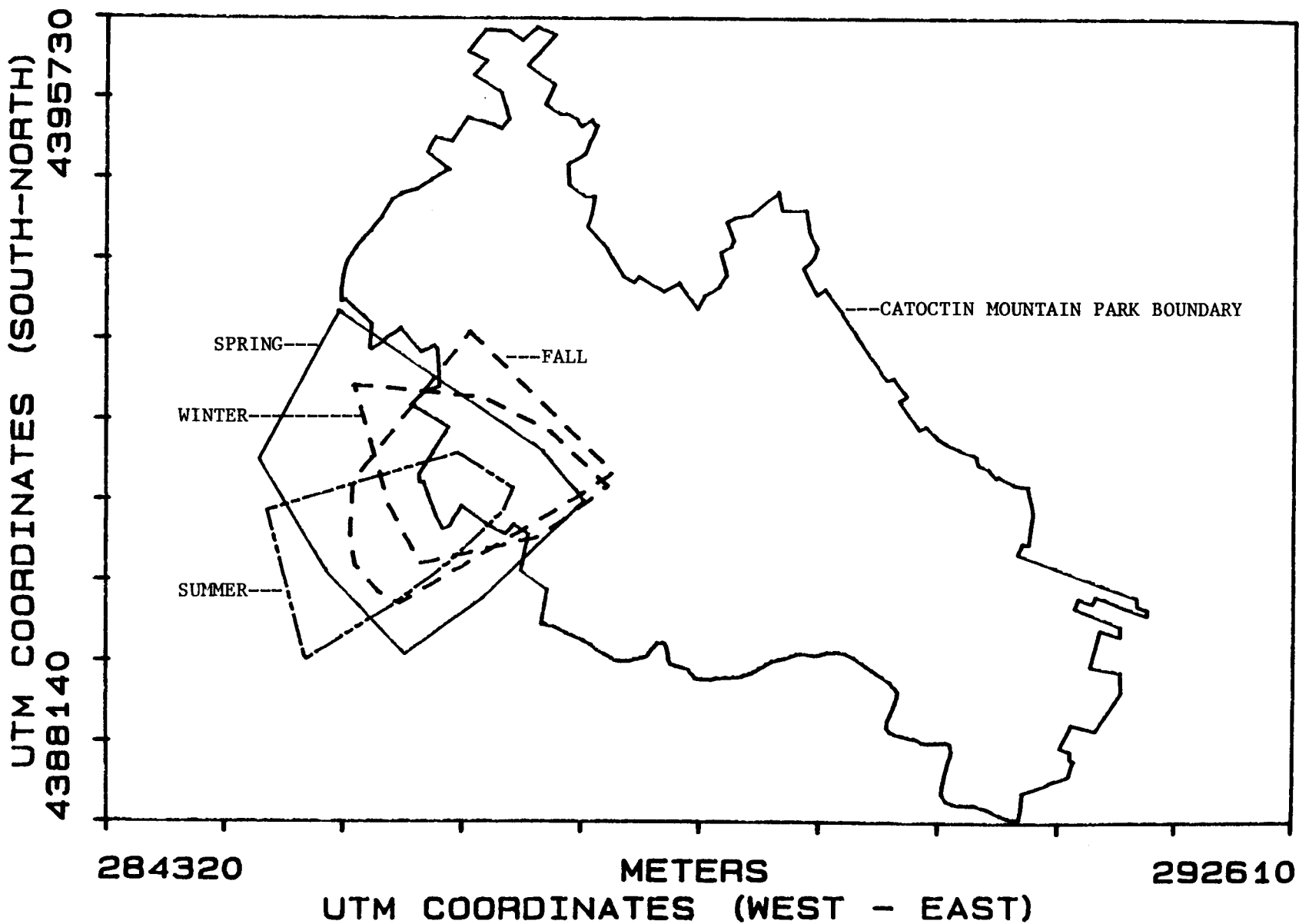


Figure 4. Seasonal home range plots relative to the park boundary for Doe No. 164.470, Catoctin Mountain Park, Maryland, 1988-1989.

SEASONAL HOME RANGES (95% MCP) OF DOE 164.513

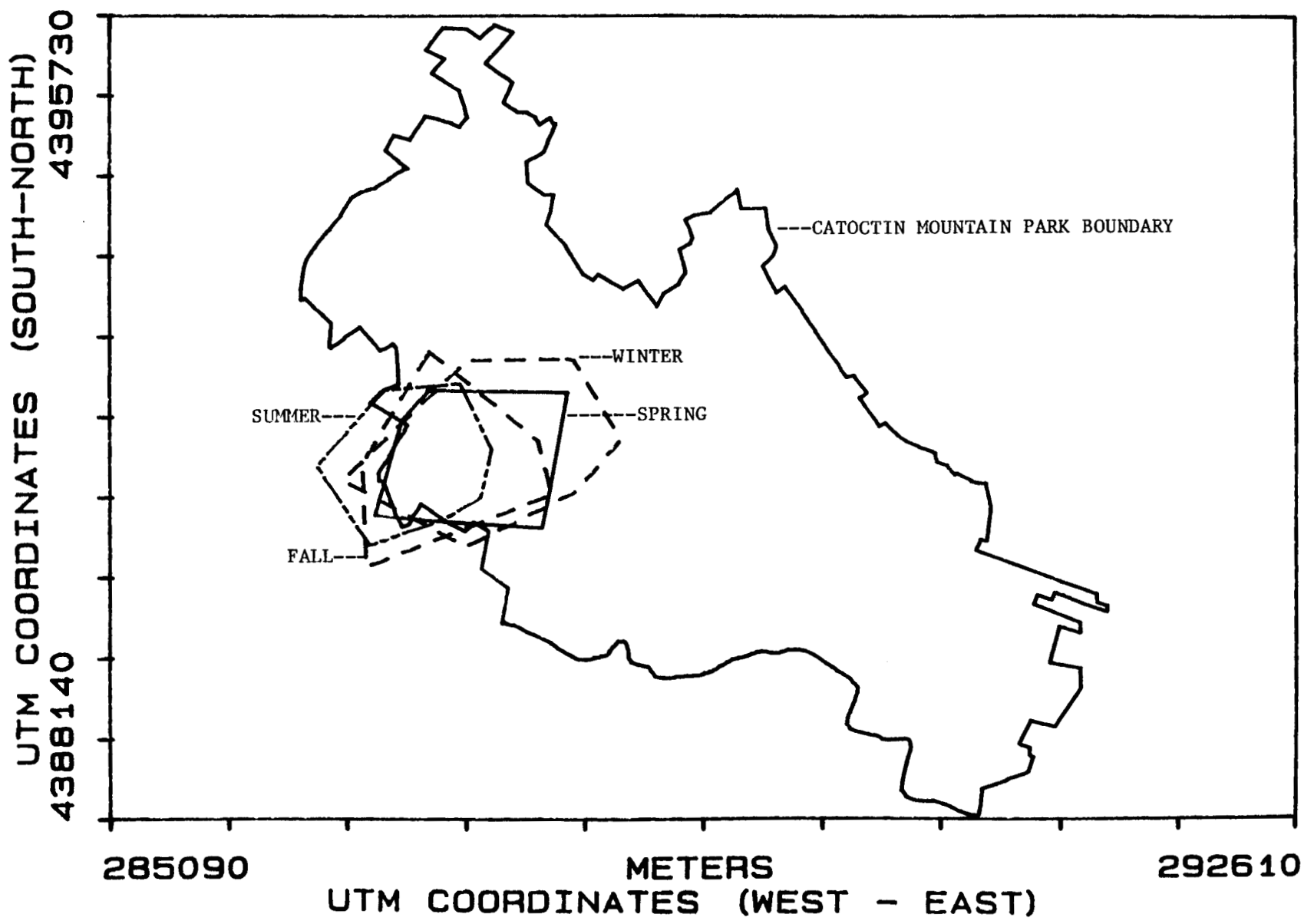


Figure 5. Seasonal home range plots relative to the park boundary for Doe No. 164.513, Catoctin Mountain Park, Maryland, 1988-1989.

SEASONAL HOME RANGES (95% MCP) OF DOE 166.813

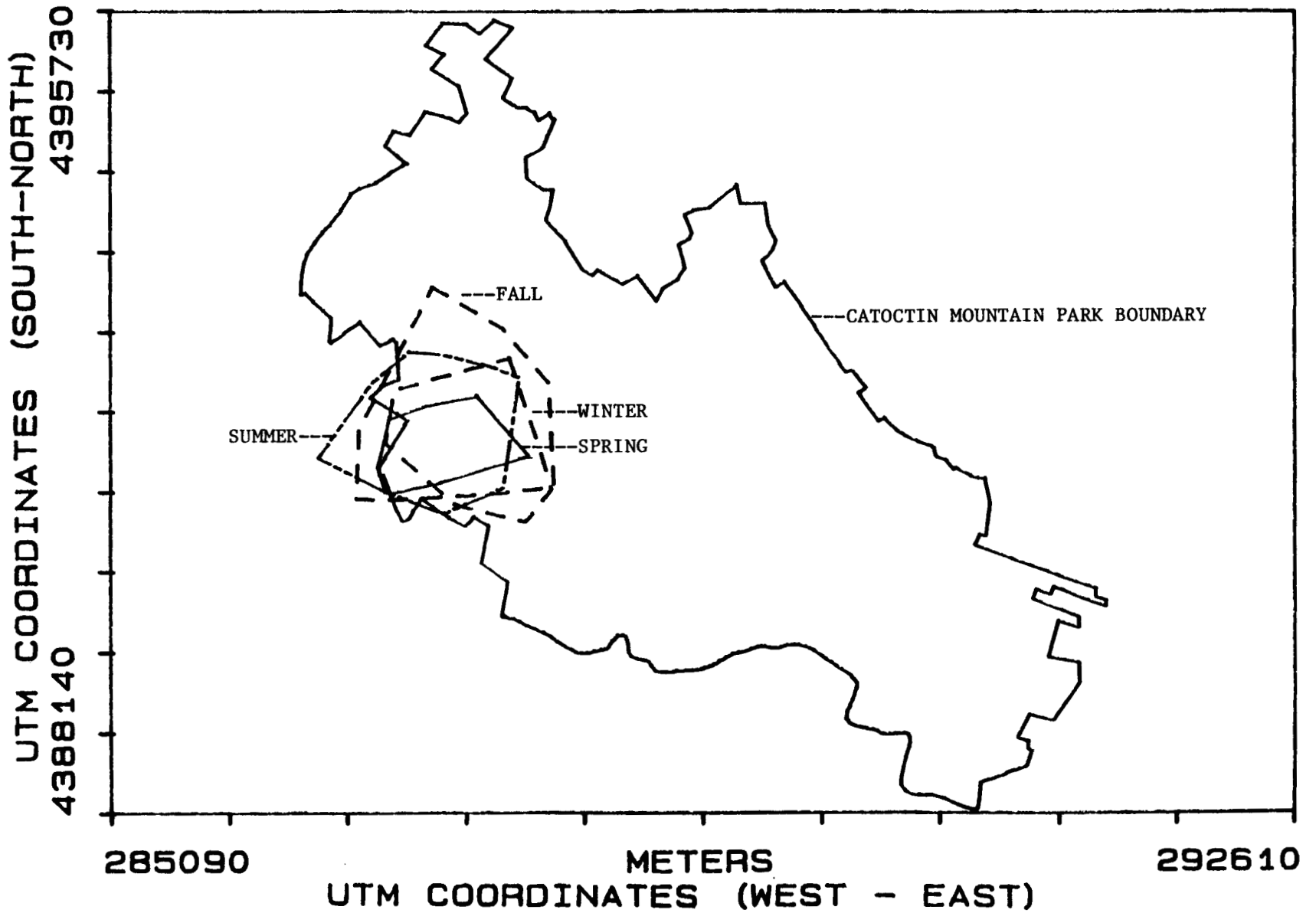


Figure 6. Seasonal home range plots relative to the park boundary for Doe No. 166.813, Catoctin Mountain Park, Maryland, 1988-1989.

HOME RANGES OF DOES 229 230 AND 740

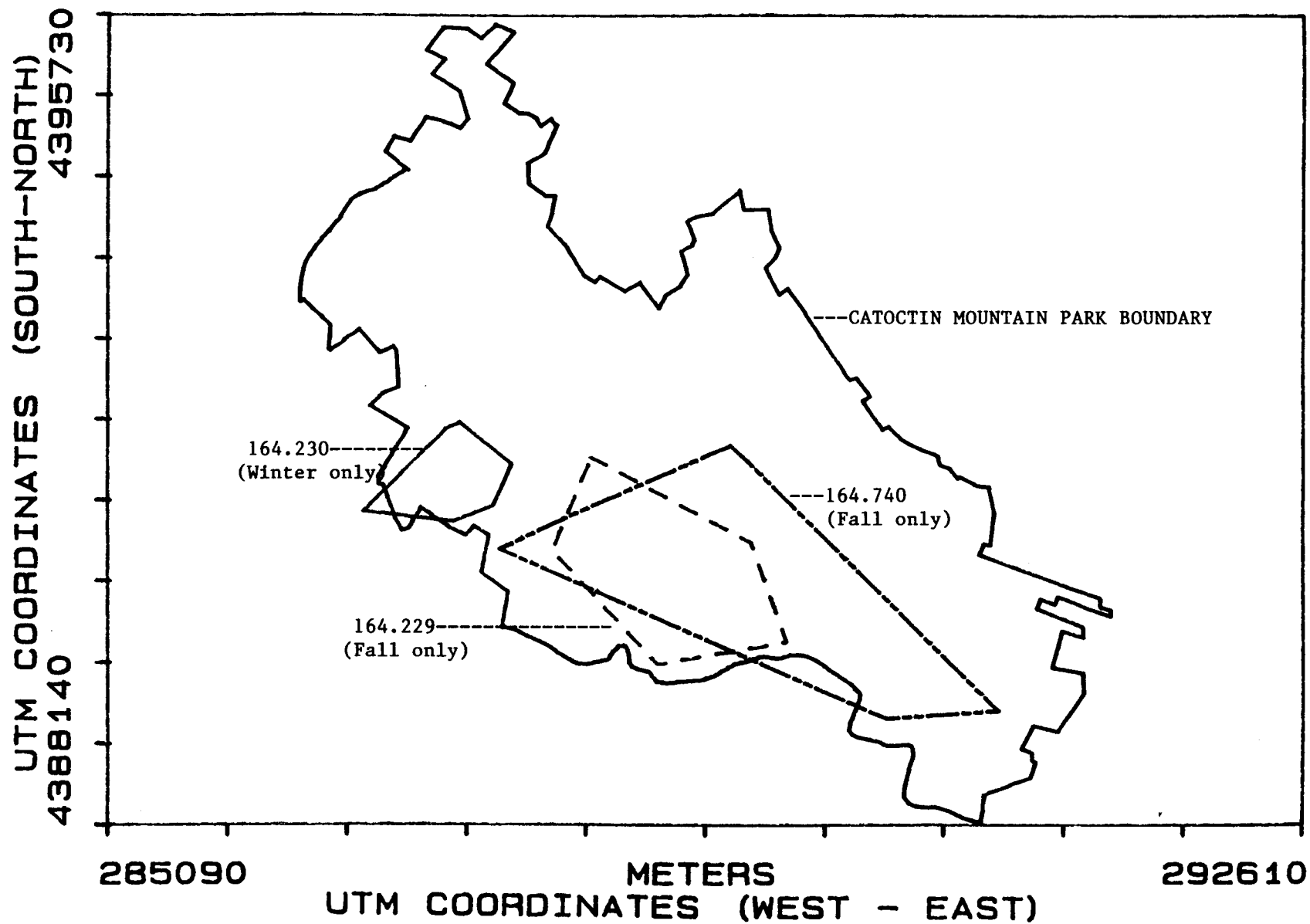


Figure 7. Limited seasonal home range plots relative to the park boundary for three different does on Catoctin Mountain Park, Maryland, 1988-1989.

regarding defecation rates of free-ranging deer (Rogers 1987), and assuming that defecation rates of CATO deer are likely to be similar to those of deer studied by Rogers (1987) in September-December (52/day), then the mean (and standard deviation) deer population estimate for the Park based on all pellet group surveys conducted in September and October 1988 is 1,308 (SD = 882), with a density of 145 deer/mi² (SD = 98). As evidenced by the high standard deviations, these estimate are not very precise and should not be considered highly accurate. At best, they will be useful when used to compare to future population estimates and densities, as long as the exact pellet group count procedures detailed in Appendix II remain unchanged from year to year.

The population estimate derived by NPS personnel from the helicopter survey in March 1989 was 549 or 61 deer/mi² (D. Roddy, pers. commun.). It is important that this population estimate not be compared directly to the one presented above using pellet group counts. Numerous potential biases exist between these two methods. The pellet group surveys were conducted in September and October, when mast was available to deer in the park. Deer may have moved into CATO in response to mast availability. The helicopter surveys were conducted in March, when forage availability is usually most limiting. Deer may have moved off of CATO to utilize foods available in areas around the park. These kinds of ecological and seasonal variations can affect deer movements, which can bias the number of deer observed during population estimation surveys.

Helicopter surveys are generally more precise than spotlight surveys (Melchior et al. 1985); however, there are numerous potential biases associated with the use of aerial surveys to estimate deer numbers. In general, most helicopter surveys consistently underestimate deer numbers (Caughley 1974, Beasom et al. 1986). Accuracy of aerial surveys is generally improved by using aerial

line transects instead of quadrat sampling in the flight pattern (White et al. 1989), by using mark-recapture estimates derived from aerial surveys (Rice and Harder 1977), and/or by using correction factors (DeYoung et al. 1989).

June, August, and September 1988 spotlight survey data were detailed in the January 1989 progress report (Appendix II). The most reliable data were obtained in late-September (i.e., at this time bucks are easily distinguishable, fawns are travelling with their does, and the lowest number of deer were classified as "unknown"--see Appendix II). Estimated sex ratios and fawn/doe ratios during this time are presented in Table 2. These data may be somewhat biased because bucks and does may not be equally observable (Downing et al. 1977, McCullough 1982). However, Downing et al. (1977) used field counts of deer during daylight hours, not spotlight counts at night. Bucks may be more equally observable relative to does at night using spotlight survey techniques as were conducted on CATO. Although, McCullough (1982) found bucks were typically underrepresented during most of the year in spotlight counts as compared to their known occurrence in the population. In a study of deer on GNMP and ENHS in Pennsylvania, which also has an unexploited deer herd, Storm et al. (1989) found deer were more visible at night with spotlights than during the day. Spotlight surveys conducted in future years on CATO will permit determination of long-term changes in sex ratios.

The spotlight survey data may reflect a skewed sex ratio in the CATO herd with does favoring bucks by a wide margin. Interestingly, Storm et al. (1989), using spotlight surveys, also found 12-15% males in the deer herd on GNMP and ENHS in Pennsylvania from 1985-1987. They also compared their spotlight data to daytime observations, to the sex composition of deer killed on roadways, and to sex composition of their radio-collared deer killed by hunters. They actually

Table 2. Summary of sex ratio and fawn/doe ratios obtained from spotlight surveys conducted in September 1988 on Catoctin Mountain Park, Maryland.

Date	No. of surveys	Sex ratios		Fawn/doe ratios
		M:F	%M	
1 - 3 Sep.	3	14:100	12.5%	0.5 fawns/doe
12 - 15 Sep.	3	15:100	13.2%	0.3 fawns/doe

observed people driving (forcing or scaring) deer from park to private land during buck hunting season for the purpose of shooting bucks. Thus, even though public hunting was not permitted on park land, some degree of buck harvest pressure occurred on their study area, and may have accounted for the apparently low proportion of bucks in the population.

This kind of unbalanced sex ratio typically results when mortality rates of bucks are higher than for does as often is the case in bucks-only harvest strategies (Hayne 1984, McCullough 1984). Bucks-only hunting invariably results in high residual populations predominantly of does, relatively low production of fawns, and removal of only about 10% of the total population. The number of deer removed under this form of harvest usually is less than the number of fawns born in the herd, and hence is incapable of maintaining a balance between deer numbers and habitat (Halls 1978, McCullough 1984).

The low number of fawns seen per doe (Table 2) indicates either very low fawn production in the herd or high over-summer fawn mortality rates, both of which can be related to an overpopulated and nutritionally stressed herd. Healthy, mature does in good-quality habitats or in well-managed populations almost always produce twin fawns every year; 10-15% of them will bear triplets (Hesselton and Hesselton 1982). The fawn/doe ratios observed in CATO were similar to those reported for the Cades Cove deer herd in the Great Smoky Mountains National Park (Burst and Pelton 1978), where an estimated 134 deer/mi² had significantly altered the natural vegetation of the area (Bratton 1979).

Driving counts during daylight hours to produce sex and age ratio data may not be highly accurate because of differences in observability among age and sex classes of deer (Downing et al. 1977). However, using spotlight surveys at night conducted by trained observers at standardized times along standardized routes

in September of each year can provide reliable data (Wood et al. 1985, Bossart et al. 1987). Thus, the fawn/doe ratios reported (Table 2) may not be highly accurate, but as long as spotlight survey procedures remain unchanged in future years, they will provide reliable indicators of long-term trends in sex ratios and fawn/doe ratios.

Deer Condition and Health Indicators

When stratified within seasons and age classes, only a relatively small sample of deer were available to evaluate condition and health indicators. Sufficient samples for statistical analysis were available only for adult body weight, kidney fat, and abomasal parasite count data (Table 3). Fortunately, the deer collected by SCWDS added significantly to the interpretations possible regarding deer condition and health. Several indicators revealed that the deer on CATO were under nutritional stress, which most likely was the result of overpopulation.

Age-specific body weights of CATO deer examined (Table 3) generally were lower compared to those that have been reported for northeastern U.S. deer in good-quality habitats or in well-managed populations (Eve 1981, Mattfeld 1984, Shrauder 1984). Body weights of adult deer did not demonstrate statistically significant differences among seasons (Table 3). Kidney fat levels were significantly ($P < 0.05$) greater in deer collected in the winter season compared to the other seasons (Table 3). Relatively low amounts of kidney fat were present in deer during summer and fall months (Table 3), and likely reflected nutritional deficiencies (Warren and Kirkpatrick 1982). In fact, the levels of kidney fat observed in these deer probably were abnormally low considering that northern deer usually attain highest seasonal fat levels during summer and fall months in order to have sufficient fat reserves to cope with nutritional

Table 3. Mean (and SD) seasonal and age class-specific condition and health indicators for deer collected on Catoctin Mountain Park, Maryland from 5 February 1988 through 28 June 1989.^a

Season ^b	Age class	Live body weight (lbs.)			Riney kidney fat index (%)			Abomasal parasite count (#)			Crude protein of rumen content (%)			Adult doe ovulations or fetuses (#/doe)		
		n	$\bar{x}$	SD	n	$\bar{x}$	SD	n	$\bar{x}$	SD	n	$\bar{x}$	SD	n	$\bar{x}$	SD
Winter	≤ 1 yr.	7	42.6	18.6	8	21.5	30.3	5	424	265	5	13.4	3.4	--	---	---
	> 1 yr.	3	88.0 A ^c	17.1	3	100.9 A ^c	81.7	2	580 A ^c	141	2	10.3	1.6	2	0.5	0.7
Spring	< 1 yr.	0	--	--	0	--	--	0	--	--	0	--	---	--	---	---
	≥ 1 yr. ^d	5	79.8 A	33.0	6	11.8 B	11.2	3	287 A	142	3	15.1	1.6	1	1.0	---
Summer	≤ 1 yr. ^e	2	30.0	0.0	2	12.0	3.0	2	0	0	2	12.5	2.8	--	---	---
	> 1 yr. ^f	6	92.5 A	6.6	6	7.3 B	5.8	6	2,800 B	1,318	1	14.5	---	0	---	---
Fall	≤ 1 yr. ^e	1	22.0	--	0	--	--	0	--	--	0	--	---	--	---	---
	> 1 yr.	2	88.0 A	19.8	2	32.0 B	45.0	2	740 A	1,046	0	--	---	1	1.0	---

^aOnly the adult age class (> 1 yr.) and only live body weight, Riney kidney fat index and abomasal parasite data were analyzed statistically for seasonal differences.

^bWinter = Jan. - Mar.; Spring = Apr. - Jun.; Summer = Jul. - Sep.; Fall = Oct. - Dec.

^cSeasonal means for adult deer (> 1 yr.) followed by dissimilar letters within a column are significantly ($P < 0.05$) different (Duncan's Multiple Range Procedure).

^dIncludes previous year's fawns.

^eExcludes deer numbers 014-88, 016-88, and 021-88, which had been supplementally fed.

^fIncludes five adult deer collected by SCWDS on 21 August 1988.

deficiencies imposed during winter (Mautz 1978).

Abomasal parasite counts in adult deer were significantly ($P < 0.05$) greater during summer than during other seasons (Table 3). The APC technique is best applied during late summer months because parasite burdens peak during this time and are thus most indicative of deer condition and health problems (Eve and Kellogg 1977, Couvillion et al. 1982). The abnormally high APC values observed in adult deer in summer (Table 3) indicated the CATO deer herd has exceeded the nutritional carrying capacity of the area (Eve and Kellogg 1977, Eve 1981, Davidson et al. 1982; also refer to the SCWDS Herd Health Check Report provided as Appendix III).

Rumen protein content data (Table 3) did not demonstrate any apparent seasonal trends; however, nutritional interpretations based solely on rumen protein content data without corresponding food habits data can lead to a misinterpretation of deer condition (Warren and Krysl 1983). Crude protein levels of rumen contents can be used to reflect protein levels in forages from ranges of different nutritional quality; however, protein levels in rumen contents are usually two to three times greater than in forages because of the microbial protein present in the rumen (Klein 1962).

Average ovulation rates were ≤ 1 /adult doe (Table 3). NPS personnel at CATO also have observed a preponderance of single fawns with does (D. Roddy, pers. commun.) Although based on a small sample, the ovulation rate data corroborate the low fawn/doe ratios observed and reported earlier under the Deer Population Numbers Section above. Reproductive indicators are perhaps the most sensitive to nutritional stress, because reproduction is one of the first physiological process to suffer under conditions of nutritional deficiencies (Kirkpatrick 1975, 1980).

Ovulation rates of adult does often are used as valuable indicators of herd and habitat condition (Cheatum and Severinghaus 1950). Ovulation and reproductive rates of yearling and adult does in good-quality, northeastern U.S. habitats usually average 1.7-2.0/doe compared to 1.0-1.4/doe in poor-quality habitats (Cheatum and Severinghaus 1950, Hesselton and Jackson 1974). Thus, reproductive rates of CATO does appear to be abnormally low, and are undoubtedly the result of nutritional stress, which likely is the result of too many deer on the Park.

One might argue that the low reproductive rates and poor nutritional status (malnutrition) demonstrated by deer on CATO is evidence that "natural processes" are at work to reduce the deer herd. To the contrary, these poor-quality condition and health indicators characteristic of CATO deer are symptoms of an "unbalanced" natural system rather than reflecting a natural process. Under "balanced," natural conditions, deer herds are not controlled primarily by malnutrition (and its effect on reproduction) and parasites. Rather, predators usually play an important role in helping to maintain control over deer herds (McCabe and McCabe 1984, Mech 1984). This discussion and its specific relevance to the CATO ecosystem are presented in much greater detail in the Conclusions and Ecological Implications Section of this final report.

Habitat Evaluations

Much research has been conducted on the food habits of deer in various regions of North America (Halls 1984). As with most wild animals, food habits for individual deer in a particular area are influenced primarily by food availability and to a lesser extent by food preferences (Korschgen 1980). Yet, given the relative preference ratings deer have for various food items, a standard technique to evaluate habitats is to conduct browse surveys to estimate

patterns and intensities of preferred versus less-preferred foods (Shafer 1965, Harlow 1984). Excessive browsing pressure on preferred food items, or their absence in an area as a result of overbrowsing, and signs of utilization of food items known to be less preferred are indicators of an overpopulation of deer.

Bramble and Goddard (1953) conducted a five-year study to determine seasonal forage preferences of white-tailed deer in 242 plots distributed through representative areas of the major forest communities in the Oak-Chestnut Forest Region of central Pennsylvania. Overbrowsing was not evident in their study (heaviest utilization of forage was 20%); therefore, forage availability was assumed to not be limiting, which otherwise could have altered forage preferences. Vegetation types in Bramble and Goddard's (1953) study area were very similar to those present on CATO, and thus their results provide reasonable indications of what forage preferences might be for deer on CATO.

A comparison of the forages listed by Bramble and Goddard (1953) to those observed on CATO that demonstrated evidence of utilization by deer revealed that several less-preferred forages have been browsed heavily by deer in the Park. These observations were not based on a specific systematic sample of the park, but rather were based on personal observations and two memoranda from the Resources Management Division at CATO (Langdon 1983, 1985; included in this final report as Appendix IV). White pine (Pinus strobus), Canada hemlock, mountain laurel (Kalmia latifolia), rhododendron (Rhododendron maximum), wild azalea (Rhododendron spp.), and gooseberry (Ribes spp.) on CATO all demonstrated moderate to heavy browsing pressure by deer. These species are all listed by Bramble and Goddard (1953) as less-preferred deer forages (i.e., normally <2% utilization). Thus, this habitat indicator also supports the conclusion that the CATO deer herd is overpopulated.

In Appalachian and northern U.S. forests, too many deer can detrimentally affect forest vegetation and can significantly alter forest communities and ecological succession (Tierson et al. 1966, Harlow and Downing 1970, Tilghman 1989). In a recent study in a 60-70-year-old Allegheny hardwood forest in Pennsylvania, Tilghman (1989) demonstrated significant reductions in tree seedling height, density, and diversity as a direct result of overbrowsing as deer population densities reached 40-80/mi². At these higher deer densities, she documented a shift in forest succession to a near-monoculture of black cherry (Prunus serotina), and profound changes in the composition of herbaceous ground cover, all of which were the direct result of overbrowsing by deer.

Perhaps one of the most significant habitat indicators of too many deer on CATO was the widespread occurrence of bark stripping. NPS personnel first noted bark stripping by deer in CATO in 1983 (Langdon 1985; see Appendix IV). The most common tree species being attacked by deer is slippery elm (Ulmus rubra). Bark stripping by deer also was reported recently in nearby West Virginia (Michael 1987). Bark stripping by red deer (Cervus elaphus) is common in some areas of Europe (McIntyre 1972). The exact reason why deer strip bark is unknown, but it may be a learned behavior (Micheal 1987). Bark stripping may be related to a shortage of forage (McIntyre 1972), and it has been proposed as a useful indicator of low forage availability for ungulates (Miquelle and van Ballenberghe 1989). Although, bark stripping by moose (Alces alces) in Alaska does not provide them with high amounts of nutrients not also available in other browse (Miquelle and van Ballenberghe 1989). In moose, there appears to be a profound difference between sexes in bark stripping behavior; females eat significantly more bark than males (Miquelle and van Ballenberghe 1989). Interestingly, the sex ratio on CATO appears to be highly skewed toward females (see Deer Population

Numbers Section above), and may be related to the occurrence of bark stripping in the Park. Bark stripping by deer on CATO represents an exacerbation of the overbrowsing problem and its influence on ecological succession in the forest. The detrimental effects of deer overbrowsing on understory vegetation and seedlings (Tilghman 1989) are further compounded by the effect of bark stripping on the midstory and overstory trees via increased susceptibility of trees to disease and mortality (Miquelle and van Ballenberghe 1989).

RECOMMENDATIONS FOR FURTHER DEER RESEARCH/MONITORING ON CATO

Research and monitoring of most deer populations for the purpose of obtaining data for making decisions regarding management actions are usually based on evaluating trends in population estimates, harvest numbers, nutritional condition, or habitat indicators (Downing 1980, Hayne 1984). Significant changes in these trends are then the basis for instituting management efforts to reduce a population that exhibits upward trends, or to increase a population that exhibits downward trends. The Pennsylvania Game Commission has satisfactorily computed specific average annual reduction rates for deer herds in all counties of the State based on antler characteristics, body weights, fawn/doe ratios, and adult sex ratios, without knowing actual population densities (Lang and Wood 1976). Rarely are deer management programs based on specific, absolute population densities, because of the difficulty and cost associated with obtaining accurate density figures for deer.

If significant budgetary increases are possible, then CATO personnel could institute a substantial effort to mark and recapture (reobserve) deer and conduct the replicated aerial transect surveys necessary to obtain more accurate population estimates (Rice and Harder 1977, Floyd et al. 1979, DeYoung et al.

1989). Deer management efforts in CATO could then be based on the objective of maintaining the deer population at a density of <18 deer/mi², at which successful northern hardwood forest regeneration has been shown to occur (Behrend et al. 1970, Tilghman 1989). Significant budgetary increases for CATO are not likely to be possible; therefore, it is unlikely that highly accurate data on population numbers will be available upon which management program decisions, and evaluations of their success, can be based.

Exact population numbers are not absolutely necessary to formulate deer management plans and to evaluate the success of these management programs. For example, if deer numbers on CATO could be reduced, then the success of this program could be demonstrated by an improving trend over several years in habitat conditions and nutritional status of deer, without any information on exact population numbers. Therefore, the following research/monitoring efforts are recommended to provide the trend data necessary for deer on CATO:

1. The pellet group count and spotlight survey methods described herein should be continued, but only in exactly the same manner as described in order to standardize the method to allow relative comparisons of trends among years. Population estimates derived from pellet group surveys conducted in two particular years likely will not demonstrate statistically significant differences, because of high variability in estimates. However, long-term increasing or decreasing trends in population estimates over several years can be used validly as the basis for management decisions.
2. The collection of deer condition and health indicators should continue and intensify in the future. Deer that have been supplementally fed (i.e., from Camp 3 or from sites subjected to

prolonged baiting) should not be included in the analysis of deer condition and health indicators as they do not reflect natural forage and habitat conditions in CATO. A greater sample size of deer and a longer-term data base for comparative purposes would be more valuable. More ovarian/uterine samples and reproductive data from adult does would provide a better indication of the reproductive performance in the herd. The herd health check as conducted by SCWDS should be repeated every year, if possible, to provide a valuable data base on trends in deer herd condition and health.

3. The deer exclosures on CATO should be monitored frequently to maintain their ability to exclude deer. They provide a valuable source of data on habitat alterations from deer overbrowsing, and can be incorporated into a program to educate agency personnel and the public on the effects of too many deer in the Park. Additionally, browse surveys should be conducted annually to determine the specific, relative utilization of preferred vs. less-preferred or sensitive vs. less-sensitive browse species (Shafer 1965, Gysel and Lyon 1980, Tilghman 1989) to document the alterations in the forest ecosystem resulting from overbrowsing by deer in CATO.
4. Efforts to evaluate fawn movements and mortality should be continued and increased. The Winter of 1988-89 was abnormally mild, and over-winter fawn mortality rates observed probably do not reflect normal over-winter fawn mortality rates for the Park.
5. In March of every year, NPS personnel should conduct standardized,

systematic searches along permanently located transects in the Park to locate deer carcasses, and count the number, age class (determined from jaws; Severinghaus 1949), and sex class (determined from the pelvis; Edwards et al. 1982) of deer dying over winter. These statistics are well related to the density of deer on an area relative to the area's carrying capacity and the severity of the winter. In overpopulated deer herds, as many as 57% of the deer can die over winter, compared to no over-winter deaths in areas of lower deer densities (Tilghman 1989). In addition, femurs can sometimes be obtained from these carcasses to determine if death resulted from starvation (Cheatum 1949).

CONCLUSIONS AND ECOLOGICAL IMPLICATIONS

Ecologists have long known that a subtle balance has evolved between most plant communities and the herbivores they support, which has been referred to as coevolution (Odum 1971:273). In natural ecosystems, herbivores are seldom food-limited; most herbivore populations are limited by predators and not by their food supply (Hairston et al. 1960). This being the case, plants in natural ecosystems are but lightly grazed (Odum 1971:225). The exception to the general lack of depletion of green plants by herbivores occurs when herbivores are protected by man or natural events, in which case they are able to deplete the vegetation whenever they become numerous enough (Hairston et al. 1960).

Perhaps nowhere other than in the field of range management has this ecological balance between plants and herbivores been better understood and managed. Range managers have long known that too many herbivores in a particular area can detrimentally alter plant communities and set back ecological

succession. They have termed this phenomenon "retrogression" or reverse succession (Stoddart et al. 1975:163). If the effect of too many herbivores remains unmanaged and for a sufficient amount of time, then an unnatural, disturbance climax or "disclimax" (Odum 1971:267) community will develop instead of the natural climax community normally characteristic of an area's ecological conditions.

When managing deer herd's to maintain this ecological balance between plants and herbivores, the density of deer, in and of itself, is not important. Rather, the number of deer in an area relative to the forage available is most important. The nutritional status and reproductive performance of deer herds is regulated primarily by forage quantity and quality, which are influenced by the relative number or density of deer in an area (Mautz 1978). Behavioral interactions among conspecifics which lead to social pressures that control some animal populations (Wynne-Edwards 1964) are not operative in deer. Supplemental feeding programs have been conducted to overcome the limitations imposed by an area's natural food supplies, and have resulted in deer populations that number four to five times greater than when not supplementally fed (Ozoga and Verme 1982), obviously indicating the lack of behavioral or social controls in deer herds.

Depletion of natural food supplies in an area can limit deer populations, but at substantial cost in terms of severely malnourished and diseased deer, and profound and unnatural habitat alterations (Eve 1981, McCullough 1984). If too many deer exist in an area relative to that area's natural carrying capacity, then forage availability usually declines, which is associated with significant habitat alterations, and which leads to a decline in nutritional status, reproductive performance, and disease resistance in the deer herd.

Under natural conditions, predators (including precolonial man) together

with other ecological forces most likely would have controlled North American deer herds (McCabe and McCabe 1984, Mech 1984). In the absence of predators and hunting by man, overpopulations of deer and deterioration of habitat quality can result because starvation and disease are not acutely operative mortality factors, but rather provide only chronically effective control over the population (Eve 1981). Under these conditions, deer populations can remain at abnormally high levels for many years until starvation, disease, or severe winter weather act to reduce deer numbers. However, by this time, severe habitat degradation can already have occurred. Recovery of habitat quality, particularly in a region of low soil quality (such as CATO), will require many years to occur. In situations of chronically overpopulated deer herds, the only ecologically sound management recommendation to prevent continued serious habitat deterioration and to suppress endemic disease outbreaks is to dramatically reduce the population (Eve 1981).

Even based on the relatively small data base collected in this project, there is no doubt that there are too many deer on CATO. Significant habitat alterations from overbrowsing by deer in the Park have already occurred and are likely to intensify in the future. If this situation continues to remain unmanaged, it likely will jeopardize the natural character of the Park's forested ecosystem for centuries to come. Numerous plant species on CATO, some of which are considered highly rare by the Maryland Department of Natural Resources' Natural Heritage Program, have already been threatened by deer overbrowsing (Langdon 1983, 1985; see Appendix IV). Numerous bird species have already declined significantly in number or vanished from the Park because of the effect of overbrowsing by deer on the understory and shrub cover in the forest (Boone and Dowell 1986).

Deer are a valued component of the forest ecosystem in CATO; however, it is obvious that they occur in the Park in unnaturally high numbers. Yet, with the land uses currently in effect in and around CATO, it is infeasible to expect natural ecological forces alone to balance the deer herd within the limits of the Park's carrying capacity. CATO is surrounded by a variety of forested and non-forested areas, some of which are at early stages of secondary succession. This diversity of habitats creates an edge effect that can produce very high deer populations (Alverson et al. 1988), which is desirable from the standpoint of wildlife management where increased game production to provide a greater harvest is the desired objective (Leopold 1933). However, in these instances, regulated public hunting helps provide the means of controlling deer populations to levels within which starvation, disease, and habitat deterioration usually do not occur.

From the standpoint of preserving natural forest communities characteristic of the northeastern U.S., these high deer populations are unnatural. Relying solely on natural forces to control the deer herd in and around CATO will almost certainly fail and result in further unnatural alterations in the forest ecosystem. Hence, it may be appropriate for man to manage and control the deer herd on CATO to maintain it within "more natural limits." In other words, it may be more "natural" for man to control CATO's deer herd within the natural limits of the area's carrying capacity than to allow overbrowsing by deer to unnaturally alter the Park's native plant and animal communities.

With these concepts in mind, and recognizing the variety of public, political, and agency concerns that exist regarding this issue, a number of management alternatives may be identified as possible solutions (some of which may be unacceptable) to the problem of too many deer on CATO.

MANAGEMENT ALTERNATIVES

Almost three decades ago professional wildlife biologists first advised the NPS that control of native animal populations in national parks may be required in order to maintain these natural areas as closely as possible to their natural state (Leopold et al. 1963). The NPS can no longer sit back passively and allow deer populations to be managed by "benign neglect" (Wauer and Supernaugh 1983). If left to control themselves, undesirable alterations of plant communities will occur. These alterations are "undesirable" from the standpoint of what the natural climax community for CATO was (Hickey 1975) prior to the widespread clearcutting that took place on the area before it was obtained by NPS (refer to the Conclusions and Ecological Implications Section for a detailed discussion).

The goal for CATO should not be to control deer, but rather should be to ensure the natural functioning of both plant and animal communities to the greatest extent possible unimpeded by human actions. The extent to which the CATO deer herd, largely because of past human actions, has already adversely affected the Park's natural communities and further threatens future successional changes, is sufficient justification to merit a policy of controlling deer numbers on the area. Yet, deer herds on NPS lands cannot be managed without regard to the public served by the NPS and their concerns for natural preservation. Thus, the solution to the problem of too many deer on CATO will be complex, will require substantial effort in public education, and may require some agency compromise.

Alternative 1 (No Action)

The first alternative to be considered, which essentially is the current deer management policy on CATO, would be the "no action" alternative. In this

instance, nothing would be done to reduce the number of deer in the Park. Under this alternative, deer would remain on CATO in numbers that are evidently too high for the area, as evidenced by the habitat and deer condition indicators presented previously. As a result, deer populations would be controlled primarily by starvation, disease, severe winter weather, and accidents (e.g., road kills). This alternative is not acceptable because the deer would occur at levels that are too high for the area, which will allow continued habitat degradation to occur (as detailed in the Conclusions and Ecological Implications Section previously). Recovery of vegetation communities in this region of poor soil quality is a relatively slow process, certainly much slower than a deer population can rebound from a herd reduction program.

Alternative 2 (Contraception)

Contraceptives have been proposed to reduce reproductive success and hence limit deer populations. While a variety of contraceptive techniques exist to control reproduction in humans, most of these methods are either ineffective or infeasible to implement in a free-ranging, wild deer population. Some of the techniques require the use of oral, synthetic steroid compounds that require daily exposure at sufficiently high levels to effect contraception. This technique generally works with captive deer where daily exposure can be ensured, but attempts to control reproduction in free-ranging deer herds with this technique have failed (Matschke et al. 1984). Research also has been conducted with microencapsulated or implantable steroid hormones in deer, but generally with less than desired results (Matschke et al. 1984). Recently, implants containing melangestrol acetate have provided at least two year's infertility in captive deer, but when applied during winter when deer are easiest to capture and treat, this approach lead to unacceptable complications because the deer were

pregnant when implanted (Plotka and Seal 1989).

A new area of contraception that may be more applicable to deer populations is immunosterilization (contraceptive vaccines). This technique uses an animal's own immune system to disrupt the reproductive system (Jeffcoate and Keeling 1984, Jones et al. 1988). This technique is currently in the very early stages of research and development in deer, and many more years are needed to fully evaluate its potential. Preliminary work in this area with feral horses has been somewhat successful (Goodloe et al. 1988, Kirkpatrick et al. 1990).

Regardless of the contraceptive technique considered, two major problems exist that likely make contraception an infeasible alternative to manage the CATO deer herd. First, most contraceptives provide only temporary sterility. Hence, continual retreatment will be required, which will be extremely costly considering the costs of capturing and handling deer. Second, the Deer Movements Section presented above showed that deer on CATO do not reside only in the Park. Any compound administered to a deer on CATO could later be consumed by a human who might have killed that particular deer in an area adjacent to the Park. This scenario has obvious concerns regarding liability. Alternatively, surgical sterilization would be permanent and could not possibly be harmful to a human who might consume meat from a sterilized deer. This approach, while being very costly, has been applied successfully to feral horse stallions (Asa 1988), which have a distinct harem-breeding system. Thus, it would be much more costly to apply in deer, because they lack a harem-breeding structure, and individual does would have to be ovariectomized to insure no reproduction.

Contraceptive management strategies, in general, would be best applied after the deer herd had already been reduced by some other method (e.g., shooting, trapping, etc.). Doing so would reduce the number of deer remaining

in the herd that would need to be treated, and hence would decrease the costs of this program. In addition, with fewer deer in the area in a shorter period of time, there is a greater likelihood that habitat recovery will occur sooner.

It is important to note that the extent to which a contraceptive management strategy would successfully reduce the number of free-ranging deer, or any wildlife species, in a particular area has not yet been documented. Even if reproduction by deer in CATO could be eliminated totally, the population could still grow by immigration from surrounding areas. Changes in the number and composition of most wildlife populations are dynamic and occur as a result of a multitude of factors, only one of which is reproduction. Deer population control must be considered and evaluated within its complete ecological context.

Alternative 3 (Poisons)

Poisonous compounds have been applied in baits to kill various pest wildlife species in some areas (Hawthorne 1984). While this technique is cost effective, it will not be feasible or acceptable to control the deer herd on CATO with this method because of significant public health concerns, non-target species problems, and public opposition.

Alternative 4 (Reintroduce Predators)

Reintroduction of native predators have been proposed as a means of helping restore the natural ecological balance in some areas. Bobcats (Felis rufus) have been successfully reintroduced to the 20,000-acre Cumberland Island National Seashore in Georgia (Warren et al. 1990). Wolves (Canis spp.) have been relocated in some areas in attempts to restore their populations (Peterson 1986). Red wolves (C. rufus) have been reintroduced to the Alligator River National Wildlife Refuge in North Carolina (M. Phillips, U.S. Fish and Wildl. Serv., pers. commun.). The endangered northern Rocky Mountain wolf (C. lupus irremotus) is

being proposed for reintroduction in Yellowstone National Park, which has been favorably supported by a majority of the Park's visitors (McNaught 1987). Most of the sites where predators have been successfully reintroduced or are being proposed for reintroduction have been relatively large and isolated natural areas. Therefore, this alternative is not likely to be a feasible solution on CATO because the Park is relatively small, there is far too much human activity in and around the Park, and the potential for human-predator conflicts is too great as a result of the density of residences and farms around CATO.

Alternative 5 (Trap and Remove Deer)

Live capture and removal of deer from CATO might be considered a possible solution, however, this method has numerous disadvantages that make it not recommendable. A variety of methods exist to successfully trap deer (Rongstad and McCabe 1984), especially at high population levels. Unfortunately, this procedure can be very costly, deer mortality can be high, and it only represents a short-term solution in that it necessitates a continuous effort to maintain the removal effort. In a long-term study on different techniques to control an enclosed deer herd in Ohio, Palmer et al. (1980) showed that live capture (using box traps, immobilizing drugs, and rocket nets) and removal alone was ineffective in controlling deer numbers in a cost-effective manner (mean man-hours per deer removed ranged from 2.8 to 6.9). Furthermore, most areas in the northeastern U.S. currently have too many deer and it would be difficult to find conveniently located areas in which to release captured deer.

Alternative 6 (Increase Deer Harvest Outside CATO)

Increasing the legal harvest of deer from areas immediately surrounding the Park might provide minimal control over deer numbers in CATO. The Maryland Forests, Parks, and Wildlife Department (MFPWD) could consider increasing the

harvest of antlerless-only deer from around the Park as a means of possibly reducing the number of deer on CATO. However, it should be noted that this program may not be very successful for two reasons. While the telemetry data collected in the Deer Movements Study suggests that does do move off of the Park routinely and thus would be susceptible to hunting pressure, deer that survive hunting pressure tend to be very elusive of hunters (Marchinton and Hirth 1984) and likely would respond to boundary hunting by staying mostly within Park boundaries. Second, the MFPWD has issued very liberal crop damage permits to most of the orchardists surrounding CATO in an attempt to reduce the damage they have incurred. Despite the fact that these landowners can essentially shoot as many deer as they want to, the problem of deer in orchards surrounding CATO has not diminished (J. Sandt, MFPWD, pers. commun.).

Deer on GNMP and ENHS in Pennsylvania apparently have been subjected to relatively heavy hunting pressure, even though hunting is prohibited on park land (Storm et al. 1989). Apparently, private citizens have been driving (forcing or scaring) deer from the park to private land during buck hunting season with the purpose of shooting bucks. While this type of deer harvest technique may not be readily applicable or desirable on CATO, it does present a possible strategy whereby more deer could be removed from the Park, without having to institute a policy change to allow direct shooting of deer on CATO. If coordinated with MFPWD personnel, and if the MFPWD were to liberalize the regulations pertaining to doe harvest in the area around CATO, then an efficient deer-harvest program could be developed in which NPS personnel could force deer off of the Park onto surrounding private land to increase their susceptibility to harvest. It is very important to note, however, that hunting on park boundaries and the proposed use of driving techniques to force elk (Cervus

elaphus) off of Yellowstone National Park to increase their susceptibility to hunters was extremely controversial in the 1960s (Woolf 1974). It is likely that a similar proposal for CATO would meet with substantial public opposition.

Alternative 7 (Direct Reduction of Deer Outside CATO)

Direct-reduction programs have been used by some agencies to control nuisance wildlife populations, and is in compliance with NPS-44. However, current NPS policy would prevent direct-reduction programs within the boundaries of CATO. NPS and MFPWD personnel could possibly be used to shoot deer along the boundaries outside and surrounding the Park; however, this method would be costly (mean man-hours per deer removed = 3.0; Palmer et al. 1980) and likely would generate public opposition. Furthermore, the effectiveness of this program would be questionable as deer likely would adapt to avoid these surrounding areas.

Alternative 8 (Public Hunting Inside CATO)

Public hunting in CATO likely would control the deer herd in a cost-efficient manner, but likely would create substantial public opposition and legal concerns. Hunting in a national park would have to be approved by the U.S. Congress, not to mention the obvious safety concerns. Limited public hunting by archers in certain non-sensitive areas of CATO would help alleviate the safety concern, but archery hunting alone is unable to sufficiently control deer herds because bowhunters success rates are substantially lower than other hunting methods (Matschke et al. 1984).

There is a precedent for hunting on NPS lands. Recreational hunting of deer by the public has occurred on Cumberland Island National Seashore, Georgia since 1980 (K. Morgan, NPS, pers. commun.). Public hunting has been conducted on Sleeping Bear Dunes National Lakeshore, Michigan since 1985 specifically to reduce and control the deer herd on that area (M. Holden, NPS, pers. commun.),

because of adverse impacts to vegetation. However, in the case of these two NPS areas, hunting is specifically permitted under the enabling legislation, which is not the case for CATO.

Public hunting also has been allowed in one well-known natural reserve (George Reserve, Michigan), and has been used to control the deer herd so as to prevent damage to vegetation in the Reserve (McCullough 1984). Interestingly, deer are the only animals (or plants) on the Reserve that are controlled artificially (McCullough 1984). Controlled public hunting also has been used as a management technique to reduce and control deer densities in experimental and research forests in the Adirondack Mountains of northern New York so that successful hardwood regeneration can occur (Behrend et al. 1970).

It is important to note, however, that some suburban U.S. residents have a negative view of hunting deer (Decker and Gavin 1987). Urban residents have actively opposed deer hunting on Fire Island National Seashore, New York even though hunting was permitted in the Seashore's enabling legislation (O'Connell 1989). Thus, an intensive educational effort would be required before a deer hunt could be instituted on CATO.

Alternative 9 (Direct Reduction of Deer Inside CATO)

Direct reduction efforts within the boundaries of CATO by NPS personnel could effectively control the deer herd. Although, direct-reduction programs by NPS personnel to control the elk population on Yellowstone National Park in the 1960s met with substantial public opposition (Woolf 1974), and likely would not be readily acceptable to the public if proposed for CATO.

A direct-reduction program would be in compliance with NPS-44. It could be conducted at night with spotlights to improve the efficiency and cost-effectiveness (Palmer et al. 1980). The collections conducted in August

1988 by SCWDS for the deer herd health check showed that deer can be collected safely and efficiently on CATO. The deer in the Park likely would avoid the roads at night, thus to ensure the success of this kind of a control effort, a varied route and time schedule would help to maintain its efficiency. Sound-suppressed or silenced rifles also could be used in the direct-reduction program to minimize disturbance to other deer or surrounding landowners.

This program could be made more publicly acceptable if the carcasses collected by NPS personnel could be made available in a useable form to feed homeless and needy people in Baltimore (or other large urban areas in Maryland). The carcasses would have to be inspected and handled in such a manner to make them suitable for human consumption. A flat-shooting, centerfire rifle with scope should be used to shoot deer in the head or neck to ensure a humane kill and to preserve the quality of the meat. Harvesting game at night to control large ungulate populations in South West Africa has been developed into a humane and economical method that complies with all health and veterinary regulations to ensure the meat is suitable for human consumption (Joubert 1985). Such a program in CATO may be acceptable to the public, because less fortunate, needy people would benefit. MFPWD might accept the program because the deer being killed would be used to benefit citizens of Maryland, to whom the deer legally belong. The program could be conducted every one to two years to control the deer population. It would best be conducted in late fall or early winter after hunting season to minimize hunter concerns, and for two other reasons. First, the meat would most likely be needed by the homeless and would be most easily processed at this time of year. Second, the program would reduce the herd before the worst part of winter so as to increase the over-winter survival potential of the remaining deer in the population.

The actual number of deer to be removed each time should be based on continual evaluations of deer population trends and herd condition/health indicators presented previously, with the approval of CATO's White-tailed Deer Technical Advisory Committee. Biological samples as described under the Deer Condition and Health Indicators Section of this report should be collected from all deer killed to be used for continuous monitoring of deer herd health. The "target levels" for deer to be removed every year or two from CATO would need to be determined based on the habitat and deer herd health data collected during the previous year. For example, if a declining trend is evident in habitat and deer condition, then more deer would need to be removed than were removed in the previous year, and vice versa. These decisions obviously would require a thorough data base on trends in deer and habitat condition. The goal of the deer herd reduction program must be the recovery of vegetation communities in the Park, and hence will require a thorough and continuous effort in collecting data on deer condition (as an indicator of habitat condition) and recovery of the vegetation community. Finally, the responsibility and authority for the deer management program on CATO should reside with the Park's Natural Resources Specialist and not the Chief Ranger.

Public information and education, and interagency cooperation would be of the utmost importance for this, or any kind of deer management program in a national park, to be successful. The U.S. Forest Service faced a problem with too many deer in their efforts to regenerate northern hardwood forests in Pennsylvania (Butt 1984). It was only through coordinated efforts and education/information sessions that agency personnel, Pennsylvania Game Commission biologists, and local hunters were able to reach a compromise (Butt 1984). In fact, this coordinated effort lead to the initiation of a major

research project on the specific effects of deer overbrowsing at various levels on hardwood regeneration, which was published recently (Tilghman 1989).

In regard to CATO, interagency cooperation may ultimately be required to maximize the chances of achieving the goal of recovery of vegetation communities in the Park. For example, if CATO were to institute a program of deer herd reduction, without similar efforts by MFPWD to reduce deer numbers surrounding the Park (as described in Alternative 6 above), then deer could potentially immigrate into CATO with the result being no net reduction in the deer population in the Park.

Alternative 10 (Exclude Deer or Control Access)

One possible management alternative, which would primarily be addressing the symptom (overbrowsing and undesirable habitat alterations) and not the problem (too many deer), would be control deer access to CATO. While it would be cost prohibitive, and probably undesirable to fence the entire park, smaller exclosures (1-20 acres) could be erected on a widespread basis around the Park to exclude deer and preserve the natural vegetative components of the forest ecosystem in these isolated exclosures. Exclosures can protect seedlings until they reach a height of 5 feet, after which they are less susceptible to deer browsing (Tilghman 1989). Of course, understory and shrub vegetation would be altered by overbrowsing if the exclosures were removed at any time. Five-strand electric fences have been shown to be cost-effective and successful in reducing deer browsing in Pennsylvania hardwood forests to the extent that natural regeneration will occur (Kochel and Brenneman 1987).

One technique that also seeks to control access and which has been used in the preservation of smaller patches of pristine forests has been to use surrounding croplands and pastures to attract animals away from the forested area

being preserved (Janzen 1983). Conservationists are realizing that it is unrealistic to manage parks as isolated "islands;" as park size decreases, the interference from natural and unnatural forces outside the park increases (Janzen 1983). Janzen (1983) stated, "As areas of conserved pristine forest are reduced in size they are increasingly susceptible to significant immigration of animals and plants from nearby anthropogenic secondary successional habitats, and the animals of the pristine forest are also likely to forage outside of the pristine forest in food-rich secondary succession." Hence, the maintenance of smaller, isolated, natural forest ecosystems (like CATO) may, in fact, necessitate the management of areas surrounding the forest. While controlling deer access to parts of the Park is one alternative, it likely is not desirable because overbrowsing would likely still occur in other areas of CATO and on surrounding lands.

Alternative 11 (Supplemental Feeding)

Supplemental feeding programs may be considered as one possible management alternative for CATO. Supplemental feeding programs likely would correct the deer condition and health problems that exist on CATO. However, supplementally feeding deer can allow herds to increase four to five fold, can be very costly, and do not prevent deer from damaging natural vegetation (Ozoga and Verme 1982).

Epilogue

The final decision as to which management alternative(s) is (are) appropriate to address the problem of too many deer on CATO will be complex, and will have to consider various ecological, public, political, agency, safety, and budgetary concerns. Indeed, the final decision likely will necessitate more than one of the alternatives presented. Palmer et al. (1980) found that any single technique alone was unable to control the deer herd on a 5,375-acre, fenced area

in Ohio; they had to use a combination of trapping, agency shooting, scientific collections, and public hunting to reduce and control the deer population.

Whatever programs are considered in an effort to reduce and control the deer herd on CATO, they should be considered objectively and seriously. One can no longer afford to avoid the issue of deer/habitat interrelations, nor the fact that the Park's plant and animal communities demonstrate inarguable evidence of these interrelations being unbalanced. An uncontrolled deer herd can significantly alter its habitat. The NPS must preserve the entire ecosystem. When one component of the entire ecosystem (e.g., deer) is seriously jeopardizing the other native floral and faunal components of that ecosystem, then drastic and possibly nontraditional management actions are justified to ensure the natural functioning of both plant and animal communities on CATO.

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