Interactions of White-tailed Deer and Vegetation at Saratoga National Historical Park

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EXECUTIVE SUMMARY

In the past decade, the National Park Service has become increasingly concerned about the high deer populations inhabiting eastern parks. This report explores the abundant population and its interaction with the vegetation at Saratoga National Historical Park (SARA). We focus on 3 principal questions: (1) what is the current state of the deer that residing on the park, (2) what is the impact of deer on the vegetation, and (3) what long-term trends can be expected in deer and vegetation?

SARA, located 32 km north of Albany, New York, includes 1100 ha. The present landscape is a mosaic of mowed fields, old fields in various successional stages, and second growth woodland. Field studies of deer began in 1985 and were largely completed in 1987. Studies of vegetation began in 1986 and were concluded in 1990. Historical abundance and growth of the deer population since the 1940's was inferred from telephone interviews with past superintendents, chief rangers and other staff. Current population size was estimated using 2 techniques, the drive method, and counts along roadways. Monthly ratios of fawns and antlered males to yearling and adult females were used to trace the dynamics of various segments of the population over time. To document seasonal-movement behavior and survival rates, we captured and marked a sample of deer with either a radio-transmitter and cattle eartags, or a thermal-plastic marking-collar. To assess physical condition of deer, we collected weight, age, sex, and morphological data from deer that were live-trapped and from incidental mortalities. We evaluated use of selected forage classes by deer by examining rumen contents of deer at necropsy. Parkwide vegetation structure, species composition and browsing impacts were determined along 14 transects during summer, 1987. Deer exclosures were erected on 3, 0.4 ha study plots in spring of 1985 to measure influences of deer browsing and cultural treatments on plant-community development. The treatments were fall burning, spring burning, and mowing. Sampling of fenced and unfenced plots was conducted from July to November in 1985, 1986, 1987, and 1990.

Results showed that deer populations at SARA began growing in the early 1960's and probably reached current levels by the late 1970's. During the 1980's, parkwide population estimates ranged from 400 to 600 deer, or 36 to 54 deer/km^2, compared to <12 deer/km^2 on

surrounding landscapes. Male:female ratios ranged from 10:100 to 20:100. Reproductive rates were 1.54, 0.92 and 0 for adult, yearling and fawn females, respectively. A total of 66 marked or radio-tagged deer provided information on movement behavior, migration and dispersal. More than half of the deer were resident on the park year-around; 29 marked deer (44%) were considered seasonally migratory, moving off SARA during summer and returning late autumn. Survival was higher in female deer than in male deer throughout the duration of this study. Graminoids and forbs were the principal diet during spring and summer, and leafy and woody browse during winter. One-third of all tree seedlings encountered were browsed. Seedlings of white ash, black cherry, European buckthorn, red maple, sugar maple, and trembling aspen were most heavily browsed. About half of all shrubs encountered were browsed and gray dogwood was heavily browsed. Within the exclosures, plant species composition was similar between unfenced and fenced areas but stem height differed significantly by 1990.

Skeletal measurements, reproductive rates and herd composition are consistent with a populations that is nearing ecological carrying capacity (K). We estimate that the current population is between 65 and 90% of K. Deer produced on SARA are contributing to the harvest in the surrounding township. Seasonal migration of the population is similar to patterns observed in agricultural environments.

The current mosaic of old-field vegetation on SARA reflects the history of human activities on the landscape. Exclosures demonstrate deer may be causing shifts in species composition in the herb layer over time, but only in some portions of the park. The principal impact of deer on vegetation is a general slowing of the pace of old-field succession. The pervasiveness of the dogwood community is attributable to deer.

In the longer term, fields will succeed to forests dominated by white ash and red maple. An irruption of the deer population followed by a dramatic crash is unlikely. Hunting on the periphery of the park will not have a significant impact on the population residing on the park. Managers must recognize that decisions about deer will largely be based on judgements of value. At present, we believe no scientific rationale exists for active management of the deer population. Continued monitoring will be integral to any future decision to manipulate either deer or vegetation.

INTRODUCTION

In the past decade, the National Park Service has shown increasing concern about the growing deer populations inhabiting eastern parks. Many national parks in the East are designed principally to interpret historical events. Often, there is a need to manage the vegetation to enhance interpretation and, in some cases, a desire to maintain a complement of rare plant species. The concern arises from the perception that the impact of deer on the vegetation may be undermining management. In 1985, we began a cooperative investigation of the interaction of deer and vegetation on Saratoga National Historical Park (SARA). The intent of this report is to characterize the ecological conditions of the deer populations and plant communities on SARA and provide a foundation on which the NPS can formulate management programs. Specifically, the report describes:

1) General ecology of deer including population size, ranging and activity patterns, food habits, and demography.

2) Impacts of deer on vegetation including species composition, structure, and successional development.

3) Recommendations for near-term management and long-term monitoring for both deer and vegetation.

Field work was begun in 1985 and behavioral studies of deer were largely completed by 1987; demographic studies of deer continued through 1990. Studies of vegetation began in 1986 and were concluded in 1990, resulting in a doctoral dissertation (Austin 1992).

STUDY AREA

Saratoga National Historical Park is located in eastern Saratoga County, New York, 32 km north of Albany along the Hudson River (latitude 43° 00', longitude 73° 78'). The park comprises 1100 ha. Elevations range from 122 m above sea level in the west to 30 m in the east on the floodplain of the Hudson River (Fig. 1). The western part of the park consists of low, elongated hills oriented northeast-southwest which alternate with broad, flat-bottomed valleys. To the east, there are two large terraces cut in an east-west direction by deep ravines formed by Mill Creek, the Kroma Kill, and their tributaries.

Climate is humid continental with long, cold winters; short, warm summers; and heavy precipitation. Average temperatures range from a low of -7 C in January to a high of 21 C in July. Mean annual precipitation is 96 cm and is evenly distributed throughout the year. Soils to the west are classified as mostly silt loams, with relatively high to moderate water holding capacity and slow permeability due to moderate to high levels of clay. Soils in the eastern part of the park are mostly silt loams and very fine sandy loams with low water-holding capacity, and rapid permeability (Heath et al. 1963).

The land-use history of SARA is primarily agricultural. Agricultural fields formed the core of the first designated Battlefield site in the late 1880's and farmlands have been added periodically to the park area since then. The present landscape is a mosaic of mowed fields, old fields in various successional stages, and second growth woodland (Fig. 2). Most of the second growth forests are relatively young (<65 yr). There are no old growth stands at SARA.

Defining the study area for ecological purposes requires that we include land outside the boundaries of SARA in the greater Stillwater-Schuylerville area. The study population consists of all deer residing either permanently or seasonally on SARA (Tacha et al. 1982), and the population to which we target biological inferences includes deer in the greater Stillwater-Schuylerville area, which extends approximately 16 km north and south of SARA along the Hudson river, and 3 km east and west. This larger landscape is similar to the that of SARA except that it is used primarily for agriculture; major crops include corn and hay.

METHODS

Deer Capture and Handling

To document deer movements and survival SARA, it was necessary to capture and mark a sample of deer from the general population. Because a single technique is rarely universally effective for capturing deer, we experimented with several methods to increase probability of success. Deer were captured over baited sites with rocket-nets designed for use on big-game animals (Hawkins et al. 1968), with Stephenson-type box traps (Masters 1978) and Clover-type box traps (McCullough 1975), with capture guns, with drive nets, and, for neonates, by hand (Downing and McGinnes 1969). Our objective was to tag 40 adult deer with radio-transmitters and as many other individuals as possible with visual markers.

Nearly all animals captured by rocket-nets or box traps were immobilized with a mild sedative. We used intra-muscular injections of xylazine hydrochloride (Rompun®, Haver Lockart, Miles Laboratories, Inc., Shawnee, KA), a non-narcotic, nonbarbiturate drug that affects the central nervous system inducing ataxia and a sleep-like state (Pomazal and Urhausen 1983). The use of Rompun in this study insured the safety of animals and researchers during processing, and reduced the risk of capture myopathy, a syndrome associated with severe stress that often leads to the animal's death up to weeks after capture (Bartsch et al. 1977).

Once restrained, weight, age, sex, and morphological characteristics were determined., and the animal was marked. Primary marks included either a radio-transmitter (Advanced Telemetry Systems Inc., Bethel, MN), cattle eartags (Fearing Duflex Cattle Ear Tags, Nasco, Inc., Fort Atkinson, WI), or a molded, thermal-plastic marking- collar (Wildlife Materials Inc., Carbondale, IL). Each animal received two numbered, metal reward-tags (one in each ear) to provide backup identification should the animal lose its primary mark, and to fulfill permit obligations to the State of New York Department of Environmental Conservation (DEC).

Historical Trends in Deer Populations

The size of the deer population inhabiting the park since its inception was inferred from telephone interviews with past superintendents, chief rangers and other staff. In addition, DEC records associated with routine winter surveys and various correspondence were used to discern population growth trends. Since 1954, the DEC has maintained records of the reported adult male (i.e., buck) harvest for the townships now comprising Deer Management Unit 40. Most of the park lies within the township of Stillwater, and a small portion of the park lies within Saratoga township. Collectively, the 2 townships comprise approximately 11% of the DMU's total land area. For this analysis, the reported buck harvest for Stillwater township was

assumed to represent the influence of the park on local deer harvests. For comparison, data for Saratoga township and all other townships of DMU 40 were plotted and rates of increase (Caughley and Birch 1971) were computed by regression of the natural logarithm (i.e., $\log_e$) of the reported harvest on time (i.e., 1954 = time index 0; Caughley 1977). Only data from 1954-83 were included in the analysis to exclude years of significant antlerless (i.e., does) harvests.

Status of the Deer Population

We obtained both an estimate and an index of abundance for deer at SARA. The drive method (Behrend et al. 1970, McCullough 1979, deCalesta and Witmer 1990) was used to estimate deer density on 3 areas of SARA. Drivers marched from one side of each area to the other, while watchers observed boundary areas, with the objective to count all animals exiting the sample area. Participants were given explicit instructions to preclude duplicate counts. Three units were selected on SARA based on their general vegetation composition, juxtaposition to well-defined boundaries such as field edges, and location. Each unit was surveyed so an accurate area could be calculated, and ground control within the unit could be established. The 3 units totaled 87 ha and represented about 10% of the total land area available within the administrative park boundary during 1985.

We counted deer during the day and night as an index to monitor seasonal and annual changes in population abundance. The total number of deer observed along a fixed route comprised our index of abundance. The route was the entire length of the Tour Road and that section of the park entrance road between the Tour Road exit gate and the Visitor Center parking lot (Fig. 1). Daytime counts of deer were conducted within 1 hour after sunrise and run routinely except when weather conditions precluded use of the Tour Road. Travel speeds were constrained between 8 and 24 km per hour. Nighttime counts were made 3 hours after sunset with the aid of a 300,000 candlepower spotlight and run on a weekly basis (McCullough 1982). For all counts, viewing conditions were coded according to characteristics of cloud cover, precipitation, and the presence or absence of fog or falling snow.

Finally, a mark-resight method (Bartmann et al. 1987) was used to estimate population size from observations of marked and unmarked animals during nighttime counts. To maximize the probability of meeting the assumptions of closed population models for mark-resight data, periods for visual recapture were restricted to May and October. These months were selected a posteriori according to the times of year when field use by deer was greatest, and significant seasonal movements were either completed (spring migration) or not yet initiated (autumn migration). This analysis was restricted to night observations because deer were affected less by our presence than during the day.

Ancillary to counts of deer along the designated route, individuals were classified by sex and age. Monthly ratios of fawns and antlered males to yearling and adult females were used to trace the dynamics of various segments of the population over time. Sampling was a with-replacement design, and precision was estimated using techniques described in Czaplewski et al. (1983).

We defined recruitment as the number fawns surviving to the next birth pulse, approximately 1 year later. This value, expressed as a ratio to a base of 100 yearling and adult females (≥23 mo), includes both breeding and non-breeding females in the denominator. We characterized productivity by: (1) recording the reproductive performance of marked females, (2) predicting fetal rates from mean yearling male antler beam diameters (Severinghaus and Moen 1983), and (3) examining reproductive tracts from a small sample of carcasses.

Three kinds of deer movements were recorded in this study: migration, seasonal shifts, and dispersal. Migration was defined as a 2-way movement resulting in a complete separation of a deer's home range into two or more geographically distinct areas. This differed from non-migratory seasonal shifts within the annual home range. Differing from migration, dispersal was defined as a one-way movement away from the natal home range.

Seasonal migration and dispersal were recorded for marked and radio-tagged deer. Telemetry was conducted daily and each individual was located 1-3 times per week. On several occasions, 12 or 24 hour radio-tracking sessions were conducted to verify the extent of movement throughout the seasonal home range. Locations for both marked and radio-tagged deer were recorded in the Universal Transverse Mercator (UTM) coordinate projection system. We tracked seasonal migration movements and dispersal of all radio-tagged deer, and for some deer with other types of marks. Dates for migration between seasonal ranges were recorded and evaluated with respect to weather and the timing of hunting season. Unless otherwise noted, we defined quarterly seasons as follows: spring (March-May), summer (June-August), autumn (September-November) and winter (December-February).

To assess physical condition of deer, we collected data from deer that were live-trapped and from incidental deer mortalities. Age, weight, chest girth, and hindfoot length were recorded. Ages of neonatal fawns were determined using morphological and behavioral criteria described by Haugen and Speake (1958). Ages of all other animals were determined by the tooth-replacement-and-wear technique (Severinghaus 1949). All weights were scaled to the nearest 0.23 kg (i.e., 0.5 pound). Both whole and field-dressed (i.e., eviscerated only) weights were recorded when possible. All linear measurements were taken with a flexible tape and recorded to the nearest millimeter (mm). In most instances, H. B. Underwood performed all field measurements to avoid inter-observer bias. Chest girth was measured by pulling the tape

tightly around the chest directly behind the scapulae. Hindfoot length was measured on the outside of the leg from the center of the heel (i.e., tuber calcis) to the tip of the hoof (Hesselton and Sauer 1973).

We used the ratio of girth:hindfoot length as our measure of condition (Bandy et al. 1956). We assumed a priori that hindfoot length would remain relatively static compared to the girth measurement, which would fluctuate seasonally in these latitudes (Mautz 1978, Moen 1978) with the accretion and mobilization of subcutaneous fat (Harris 1945). While this would not be strictly true for growing animals, this method seemed to be the best compromise between developing an index that was both sensitive and easy to measure. The ratio was computed by subtracting the $\log_{10}$ transformed hindfoot measurement from the $\log_{10}$ transformed girth measurement. This method removes the effect of body size differences in morphological characters related to age and gender. Differences in condition were explored by season, sex and age group using the general linear model (Freund et al. 1986).

Survival was estimated from the sample of marked deer on SARA using the Kaplan-Meier product limit method (Kaplan and Meier 1958) with a staggered entry design (Pollock et al. 1989). Causes of death were determined from necropsies of animals found dead in and around SARA. Yearly data were pooled, and categorical analysis (SAS Institute 1986) was used to test deer age group (i.e., fawns, yearlings, and adults), sex, migration status and condition for prognostic value. Utilization of selected forage classes by deer was evaluated by examining rumen contents of deer at necropsy and through anecdotal observations of foraging deer. Rumen examinations followed Chamrad and Box (1964). We used three mesh sizes: 0.64 cm, 0.32 cm, and 0.16 cm to separate identifiable plant fragments. The sample was then washed through the sieves until all the rumen fluid was rinsed from the contents. Samples were processed immediately or stored in quart-sized polyethylene bags and frozen. A 100 pin point-frame sampling device was used to quantify rumen contents (McCullough 1985). The sample was spread evenly in a lab tray to form a layer of material about 2 cm thick. Two passes through the rumen contents, with stirring between, permitted the calculation of mean occurrence of forage items.

To verify volume to area relationships in certain forages, a 100 ml subsample of rumen contents was removed from approximately half of the rumens analyzed with the point frame. This subsample was separated into components of lowest taxonomic level possible, and each was volumetrically displaced in a graduated cylinder. Regressions of forage class volume on respective point-frame scores were performed to verify relationships, and to provide equations to correct potential biases in the point-frame technique.

Forage use was summarized by computing an index of importance for each forage class by season. The index was composed of the product of the frequency of occurrence of the forage class in rumens (i.e., the number of rumens containing items in that forage class), and the total aggregate volume of the forage class (McCaffery et al. 1974). These indices were scaled to a percentage of the total for the season to yield a value of relative importance of each class (0-100%).

Climatological Observations

Daily climatological observations were collected routinely by park staff at 1 of 2 weather stations. Most weather observations were recorded at the weather station located at Stop One on the Tour Road (Fig. 1). During the non-fire season, which usually began with the first significant (>15 cm) snow fall, weather observations were recorded at the maintenance facility station (Fig. 1). Regression formulas were developed to predict missing data points using statistical relationships between climatological variables collected at SARA and the Albany County Airport (NOAA National Weather Service, Albany, N.Y., WSFO AP), or values were interpolated between adjacent records.

Vegetation Composition and Structure

Parkwide vegetation structure and composition were sampled by the point-centered quarter method (Cottam and Curtis 1956) along 14 transects during summer, 1987. Transects were located 152 m apart and oriented 43° NE - 223° SW across the park with the exception of 1 transect which was located perpendicular to the previous thirteen. Sample points were located by pacing along compass bearings at intervals of approximately 152 m. The area around each point was divided into quarters, using the transect direction and its perpendicular for reference.

Percent sunlight interception over the center point and percent ground cover at the center point were estimated with a mirrored periscope. The tree, sapling, seedling, and shrub closest to the center point in each quarter were identified. A tree was defined as a woody plant with ≥ 10.3 cm diameter at breast height (dbh). Similarly, a sapling was defined as a woody plant ≥ 1 m in height and with dbh < 10.3 cm. A seedling was defined as a single woody stem < 1 m in height, and shrubs were defined as either single or multi-stemmed woody plants < 2 m in height and with no determinable dbh. Distance from the center point, dbh, status (live or dead), and height were recorded for each tree and sapling. Distance from the center point,

status, and height were recorded for each seedling and shrub. Relative density (RD), relative frequency (RF), relative dominance (RDo) and importance values ($IV_{trees \& saplings}$ = RD + RF + RDo; $IV_{seedlings \& shrubs}$ = RD + RF) were calculated. Nomenclature follows Gleason and Cronquist (1991).

Effects of Deer Browsing on Vegetation

Two measures of the biotic effects of deer browsing were evaluated on each individual in the four quarters and various strata. The pattern of utilization was recorded as browsing evident on terminal twigs, lateral twigs, or both. The intensity of browsing was determined by calculating the proportion of browsed to unbrowsed stems and placing the resulting estimate in an intensity class (0% = none, 1-25% = light, 26-50% = moderate, 51-75% = heavy, or 76-100% = severe). The height to the highest browsed stem for each individual was also measured to examine the vertical profile of deer use. These impacts were summarized by species to determine the influence that deer browsing exerts on vegetation composition and development.

Four, 0.4 ha exclosures were erected at 4 sites in spring of 1985 to measure influences of deer browsing and vegetation manipulation on plant-community development. Adjacent to each fenced plot, a similar unfenced 0.4 ha plot was established. The Exclosures were established in areas selected to represent a range of old-field plant-community types found on the park. Records indicate that the Exclosure 1 site had been mowed annually for several decades until 1985 when the Exclosure was constructed. In effect, then, this field is the earliest stage of succession of the 3 areas. The field is bordered on 3 sides by mixed woods. The Exclosure 2 old-field site is a shrubland with scattered white pine, white ash, American and slippery elm, and wild black cherry. The field had been mowed annually until about 1970, when it was abandoned, and hence is the oldest from a successional perspective. The Exclosure 3 site is structurally similar to the Exclosure 2 site, but is more open. American and slippery elms, white ash, and white pine are scattered among large clumps of gray dogwood. A severe fire burned through the area in 1977, and this field is considered successionally "intermediate" in this study. A fourth Exclosure was located in an even-aged, second growth woodlot dominated by several species of oaks, red maple, sugar maple, cottonwood, yellow birch, and gray birch with a dense fern understory. The large component of early successional tree species suggests that this area was an abandoned plowed field, however, its precise age could not be determined. The data from this site are not included in the analyses reported here.

The areas within each fenced and unfenced plot were divided into quarters, and 3 treatments (plus control) were assigned randomly to each quarter. The treatments were fall burning, spring burning, and mowing. Fall burns were conducted during the week of September

30, 1985, after the first hard frost. Spring burns were conducted during the week of April 16, 1986. Plots were mowed twice, once during the week of April 16, 1986 and again during the week of October 10, 1986.

Sampling of fenced and unfenced plots was conducted from July to November in 1985, 1986, 1987, and 1990. The Exclosure sites were sampled in the same order every year. Species cover and height were sampled in each 0.12 ha treatment plot by placing 5 east-west, 30 m transect lines at 3 m intervals in each plot. Three 0.20 m^2 (20 x 100 cm) quadrats were placed at 7 m intervals along each transect line, giving a total of 15 quadrats for each plot. The 15 quadrats were considered a single, systematic sample for each treatment plot, though transect and quadrat locations varied somewhat from year to year.

Pre-treatment 1985 species cover estimations were completed where time permitted. In each quadrat, all plant species and the height of the tallest individual of each species were recorded. Cover was defined in this study as the proportion of ground covered by the perpendicular projection of the aerial parts of a plant rooted within the quadrat. Cover was estimated for each species and assigned to a cover class scale: 1 = 0-1%, 2 = 2-5%, 3 = 6-10%, 4 = 11-25%, 5 = 26-50%, or 6 = 76-100% (modified from Daubenmire 1959). Mean percent-cover of each species was determined by multiplying the frequency of an individual species' occurrence in a particular cover class by the midpoint value of the cover class summed over the 15 quadrats in each plot. Relative frequency of each species was determined by dividing the frequency of each species by the sum of frequency values of all species over the 15 sample quadrats. An importance value was derived for each species by summing the mean percent cover and relative frequency values. The complement of Czekanowski's index of similarity (Goodall 1978) was computed for each treatment plot using importance values of the 10 most important species sampled in each year. Principal Coordinates Analysis (PCO) was used to ordinate the vegetation community (Pielou 1984) among treatment plots within years, and among years within treatments in an attempt to differentiate treatment and deer effects.

Trends in vegetation succession in various regions of the park were determined from parkwide transect sampling and the Exclosure study. At points along transects where 1 or more dead trees were tallied, sapling and seedling composition was determined. In addition, tree seedling regeneration was examined at each Exclosure in 1990 (i.e., the end of 5 complete growing seasons). Fifteen 4 m^2 (200 x 200 cm) quadrats were located at the same points used for cover estimation in each treatment plot. All tree seedlings were identified and counted, and the height and leader length of each were measured. Stem density, leader lengths and height class profiles were compared at Exclosure site.

RESULTS

Deer Capture and Handling

Between January 1985 and July 1987, we made a total of 146 captures involving 136 different deer (Table 1). With the exception of neonatal fawns, all deer were captured between the months of November and March with rocket nets, Clover and Stephenson box traps. Radio-tags were placed on 57 deer, aged 9 months or older, and cattle ear-tags were placed on an additional 20 animals (Table 2). Two confirmed trapping-related mortalities were recorded. Among animals aged ≥4 mo, females were captured at a frequency 4x that of males (Table 3). A sample of 58 neonatal fawns was captured: 21 received radio-tags, 25 received cattle eartags, and the remaining 12 were released unmarked; however, none of these deer were included in any analyses for this report.

Historical Trends in Park and Regional Deer Populations

Based on responses to questions during telephone interviews, deer at SARA were not noticeably visible until the early 1960's. By the mid 1970's, the deer population at SARA was large enough to warrant correspondence between the superintendent, regional chief scientist, and the DEC. The first park superintendent, 1941-47, reported "not seeing too many deer", but did see deer on occasion. Additional anecdotes by local hunters suggest that deer sightings in those days were a rare event. These observations are corroborated by local harvest statistics (Fig. 3). Rates of population increase calculated for Stillwater, Saratoga and other DMU 40 townships were 8, 8 and 2% per year, respectively. Over the 29-year period between 1954-83, these differences in population growth easily account for the fact that Stillwater township supports an annual buck-harvest that is 5x greater than the much larger area comprising DMU 40.

Status of the Deer Population

We conducted 6 deer drives from 1985-90 (Sep-Oct). Based upon the interior 10.9 km^2 of SARA, mean density for the 6-year period was 38 deer/km^2. Parkwide population estimates derived from density during this time period ranged from 321 to 512 deer ($\bar{x}$ = 409, CV = 20%; Table 4). Mark-resight estimates of population size ranged from 242 in May, 1985 to 527 in October, 1987 (Fig. 4). Confidence intervals around estimated population sizes were large due to the relatively small number of marked animals available on the study area at any given time.

We conducted 120 counts along a fixed route within 1 hour after official sunrise between May 1985 and December 1987. An additional 96 counts were conducted within 3 hours after official sunset. Analysis of variance demonstrated that a model including just year and month was a sufficient predictor of deer numbers during night-time counts ($R^2 = 65\%$). However, nearly all the variation in deer numbers was attributable to the month rather than year (Table 5), suggesting strong seasonal influences. Visibility at the time of survey was important only for counts conducted within 1 hour after sunrise. The day-time model included effects for year and month (Table 5) and was also a good predictor ($R^2 = 72\%$) of deer counts.

In general, seasonal trends in the number of deer counted were similar for both daytime (Fig. 5) and nighttime (Fig. 6) periods, but the significance of time trends was ambiguous. Nighttime counts indicated no significant change in the population over the 3 yr period, while day-time counts suggested a slight increase in deer abundance in 1986 and subsequent return to lower abundance in 1987.

Through the 12-month period beginning 1 June, the male:female ratio showed considerable variation. The ratio increased gradually reaching a peak just prior to the breeding season, then declined, exhibited a brief increase during the mid-breeding season, and dropped sharply through winter and early spring. Peak male:female ratios ranged from 10:100 to 20:100. Ratios of antlered males per 100 females showed a consistent year-to-year pattern (Table 6).

The estimate of the proportion of reproductive yearling females derived from marked deer was higher than that predicted from a small sample of reproductive tracts (Table 7). Reproductive rates (i.e., the product of the fraction breeding and fetuses in-utero) predicted from antler-beam diameters of yearling males ($\underline{n} = 101$) were 1.54, 0.92 and 0 for adult, yearling and fawn females, respectively. These estimates were similar to those from the marked sample of deer on SARA. Reproductive rates for female deer in the greater Stillwater-Saratoga region were: adults, 1.76; yearlings, 1.37; and fawns, 0.27.

There was a steady increase in the ratio of fawn:doe from immediately post-parturition through October, followed by a noticeable decline from January through March (Table 6). An early-winter ratio of 132 fawns per 100 does recorded in 1985-86 was higher than that in any other year; however, recruitment was approximately 50 fawns per 100 does and was similar among all years.

A total of 66 marked or radio-tagged deer provided information on seasonal shifts in movement behavior, migration and dispersal. More than half of the deer were resident on the park year-around. A small number of year-long residents demonstrated seasonal shifts in their

annual home range, while others showed no apparent shifts. A total of 29 marked deer (44%) were considered seasonally migratory, moving off SARA during summer and returning late autumn or early winter. All but one of the migratory animals were adult females with their respective offspring; the exception was the only adult male tagged during the study. The principal migration routes paralleled the Hudson River. Migrant deer travelled distances up to 16 km north and south and 6 km east and west.

The timing of migration was consistent among years and appeared to be tied to weather conditions, particularly snowmelt in spring and temperature in autumn (Fig. 7). Spring movements to summer range were highly variable. Many animals moved a short distance and remained between ranges several days before completing the movement to summer range. Movements back to winter range during autumn were more direct but transitory in nature. Transitional movements were often made at night and frequently on consecutive days. Some animals made trips between ranges several times before becoming sedentary. In each year, mean fall migration dates preceded the deer hunting season by as many as 30 days. However, some deer made transitional movements throughout the hunting season and 52% ($\underline{n}$ = 78) of all marked deer aged >6 months were subsequently harvested during the deer hunting season. Most of the dispersing deer were yearling males. One adult female crossed the Hudson River, but died shortly thereafter from injuries sustained while attempting to jump a woven-wire fence. It is uncertain whether the movements of this animal constituted migration or dispersal.

Physical condition, as indexed by girth:hindfoot ratios differed among seasons and by age group within seasons, but not by sex (Tables 8-11). Deer experienced peaks and nadirs in body condition during autumn and spring, respectively (Fig. 8). Trends in condition by age group (Fig. 9) showed that, in general, fawns were in poorest condition, followed by yearlings and then adults. Heart girth was significantly affected by season, age group, and sex (Table 12). Hindfoot length was affected only by age group and sex, validating its use as a suitable control for age and sex in interpreting relative fatness throughout the annual cycle.

Survival was higher in female deer than in male deer throughout the duration of this study (Tables 13 and 15). While a minimum 20 female deer survived to the end of the field work, no male deer were known to have survived. Crude estimates of marginal survival for males demonstrated that the majority of deaths were attributable to hunting (Table 16). Most deaths in females were attributable to agents other than hunter harvest (Table 14) until 1987 when hunting regulations on surrounding lands changed from bucks-only to either-sex harvest. A comparison of 1985 and 1987 data showed that the change in regulations resulted in a 17% decrease in annual survival rate (i.e., p_x) of migrant females.

Fawns comprised the largest percentage of the sample of dead deer examined at SARA (Fig. 10), followed by yearlings and adults, respectively. The sexes were nearly equally represented in the sample as well (Fig. 11). Automobiles were the most frequent, determinable cause of mortality in deer around the park occurring primarily in the early spring and early autumn. Predation by dogs and coyotes and debilitating condition (including malnutrition and disease) were the next most frequently encountered causes of death in deer. These losses were restricted to the winter and early spring months when deer were in a state of advanced physiological stress. However, the importance of automobiles and hunter harvest were greatly over- and under-emphasized, respectively, when compared to causes of death in the marked sample of deer (Fig. 12). During the springs of 1986 and 1987, we transported several deer that died of mysterious causes to the DEC's Wildlife Pathology Lab in Delmar, NY. Laboratory analysis revealed the proximate causes of death as bacterial infections. We did examine more animals that showed similar symptoms, that in retrospect, were probably deaths by similar causes. However, these cannot be confirmed, and consequently are reflected in the unknown category.

We examined 53 rumens for forage-class utilization. Seasonal patterns in use of forage classes were evident (Fig. 13). Graminoids and forbs dominated the spring and summer diets, while use of leafy and woody browse was restricted to periods when grasses and forbs were either unpalatable or unavailable. Seeds and fruits, particularly natural mast and fleshy fruits (e.g., acorns, apples, dogwood and common buckthorn drupes), constituted nearly 100% of most rumens collected in the fall. Acorns were selected over all other types of seeds and fruits including apples.

Current Vegetation Composition and Structure

Based on sampling and existing cover maps, we classified the vegetation of SARA into 4 general types:

1) Closed-canopy Woodland - generally even-aged, consisting of trees 18 m tall and > 80 years old. Closed-canopy woodland occurs over a relatively small portion of the park, primarily in the British Woods (i.e., southwest of the Stop 8 area), in the wooded areas north of Stops 3 and 10, and in steep sloped ravines. The closed canopy woodland of SARA contains approximately 494 trees/ha, with a mean basal area of 593 cm^2/stem. Mean sunlight interception is 78% (SE 3%) and ground cover is 11% (SE 2%). Based on ecological importance values (IV), the closed-canopy woodland is dominated by white pine, red maple, and northern red oak (Table 17). American beech and eastern hemlock are found on east-facing slopes

and ravines associated with a few understory trees and ferns. More mesic and middle slope sites are dominated by northern red oak, red maple, and sugar maple with eastern hop-hornbeam, and hornbeam. Northern red oak, white oak, and red maple are found on upper, steeper slopes with gray dogwood and maple-leafed viburnum undergrowth. In wet woods, tree species include red maple, northern red oak, quaking aspen, big-toothed aspen, white oak, and yellow birch. Huckleberry is a common shrub in these areas. Witch-hazel is found on wet hillsides, and northern prickly ash occurs infrequently in more mesic sites.

2) Open Woodland - areas dominated by a mixture of trees and shrubs. Open woodlands contain approximately 246 trees/ha, with a mean basal area of 453 cm^2/stem. Mean sunlight interception is 42% (SE 4%) and ground cover is 51% (SE 4%). Dominant tree species include white pine, elm, wild black cherry, white ash, and red maple (Table 18). Large clumps of gray dogwood and other shrubs such as nannyberry and arrow-wood are present. Speckled alder and red-osier dogwood occur infrequently in wetter areas.

3) Old Fields and Shrublands - areas dominated by a mixture of perennial grasses and sedges, with >50% cover of shrubs and scattered trees. Average density of shrubs and trees is 220 stems/ha. Ground cover is typically >70%. Gray dogwood dominates these areas. Tree density is sparse and composition is almost exclusively American elm, slippery elm and white pine. Small trees such as common buckthorn, hawthorn, and apple are common in areas that were once pastures and orchards. (All subsequent reference to elm in this report includes both species.)

4) Managed Fields - areas dominated by grass and shrubs that are maintained by mowing or burning including roadsides, walkways, and historical overlooks. Plant communities in these fields are composed primarily of Kentucky bluegrass, ferns and various forbs. Tartarian honeysuckle and steeplebush are commonly found along roadsides, and black willow is found along open watercourses in association with dead or dying elm trees.

Effects of Deer Browsing on Vegetation

White pine, by virtue of its morphology, was the most extensively browsed tree, often to heights of >2 m (Table 19). Sapling-sized stems, including small trees associated with open woodland, were also frequently browsed (Table 20). One-third of all tree seedlings encountered were browsed. Seedlings of white ash, wild black cherry, common buckthorn, red maple, sugar maple, and quaking aspen were most heavily browsed (Table 21). About half of all shrubs encountered were browsed, most of them both terminally and laterally with relatively heavy intensity (Table 22). More than two-thirds of the shrubs categorized as severely browsed were gray dogwood. Other shrubs that were heavily utilized included nannyberry, maple-leafed viburnum, arrow-wood, and huckleberry.

The mean maximum number of leading dominants shared among pairwise comparisons of treatment plots over time (4 treatments x 3 sampled years; $\underline{n} = 12$) was 7.5 (SE = 0.162), and the mean minimum was 3.9 (SE = 0.253). Similarly, mean maximum and minimum numbers of shared leading dominants among treatment plots in a given year (3 exclosure sites x 3 sampled years; $\underline{n} = 9$) were 7.8 (SE = 0.124) and 4.0 (SE = 0.459). Within treatments, spring burns and mowing produced the most pronounced changes in plot character over time based on the 10 leading dominants (Figs. 14-16). Fenced and unfenced differences were smaller in these treatment plots relative to other treatments. Ordinations among treatments within each year revealed marked dissimilarities in control plots from fenced and unfenced locations at each exclosure site. Over time, however, these differences diminished and plots tended to converge in character (i.e., relative importance of leading dominants) (Figs. 17-19) with the exception of those in Exclosure 3, which diverged along a fenced-unfenced gradient (Fig. 19). Fall burns tended to be most similar to control plots regardless of time, while mowed and spring burn plots tended to be least similar to controls.

After 5 complete growing seasons, a total of 679 seedlings representing 13 genera were tallied in all fenced and unfenced plots. White ash, red maple and common buckthorn were the most frequently encountered species, comprising over half of all stems tallied (Table 23). Seedling density, though differing at each exclosure site, was not significantly different ($\underline{P} > 0.90$) between fenced and unfenced plots. However, a trend is evident in the data for a slightly lower density in unfenced plots (Fig. 20). Leader lengths differed significantly ($\underline{P} < 0.01$) among exclosure sites and fenced -vs- unfenced plots. Seedlings established in fenced plots had leaders which were, on average, 16% (SE = 7) longer than for seedlings in unfenced plots (Fig. 21). Comparisons of height class distributions within and outside of fenced plots shows a trend toward more seedlings being recruited into larger height classes (Figs. 22-24).

At points where dead elm trees were tallied, elm and white pine dominated overstory vegetation (Table 24). Sixty-two percent of all tree-sized elms tallied were dead. Elms were also the most important sapling-sized species tallied in the understory around these points (Table 25). However, white-ash attained the highest importance in the seedling stratum relative to all other species followed by common buckthorn, wild black cherry and red maple (Table 26). At points where dead trees of other species were tallied, white pine, quaking aspen, red maple and northern red oak were the most important overstory constituents (Table 27). Under these canopies, red maple was the most important sapling- and seedling-sized species relative to all others tallied (Tables 28 and 29).

DISCUSSION

Three principal questions precipitated our research at SARA: (1) what is the current state of the deer population residing on the park, (2) what is the impact of deer on the vegetation, and (3) what long-term trends can be expected in deer and vegetation? We believe that there is a larger question surrounding the ecological determination of overabundance, which heretofore, has not been addressed for eastern national parks. We will discuss each of these questions, in turn.

Deer Population

Populations on SARA during this study were estimated to be 400 to 600 animals, or about 36 to 54 deer/km^2 (90 to 135 deer/mi^2). This density is similar in magnitude to those observed in other eastern national parks where hunting is prohibited (e.g., Burst and Pelton 1978, Christie and Sayre 1989, Storm et al. 1989) In contrast, deer populations on the surrounding landscape are estimated to be <12/km^2, and since 1984, have been subjected to annual harvests of antlerless deer. The population sex ratio is skewed toward females. The skew is a result of male-biased dispersal out of SARA and the added pressure on antlered males during the hunting season on surrounding lands. However, similar ratios have been documented in other park populations (Christie and Sayre 1989, Warren and Ford 1990) and in other populations subjected to a "bucks-only" harvest regime (McCullough 1984).

The skeletal measurements, reproductive rates and herd composition estimates are consistent with a population that, from a demographic sense, is nearing its upper limit imposed by environmental pressures. McCullough (1979) refers to this upper limit as K-carrying capacity, or just K. In theory, K includes all the components that might limit further population

growth including food, water and shelter. However, rarely are any of these components measured; instead, biologists index their combined effects by the number of animals that survive through critical shortages (Hamlin and Mackie 1989). Though it could be argued that the existence of K has never been "proven", there are several demographic milestones that indicate the likelihood that a deer population will sustain further growth (McCullough 1979, Downing and Guynn 1985).

It is generally accepted that the principal mechanism limiting deer population growth near K is declining recruitment of young. Because of their small size and greater energetic demands relative to adults, deer 6-11 months of age are disadvantaged both socially and physically during periods of low resource availability (Hirth 1977, McCullough 1979). As deer populations approach K, competition for resources intensifies. Because they are poor competitors, young animals tend to show the first signs of physiological stress, and our data support that observation. The physiological condition and reproductive rates of yearling and adult females suggest, using the criteria of McCullough (1979) and Downing and Guynn (1985), that the deer population at SARA is between 65 and 90% of K. Total populations on SARA therefore would be expected to peak at 550 to 750 deer, or 48 to 64 deer/km^2 (120 to 160 deer/mi^2). Yearling females are sufficiently stressed that 36% ($\underline{n}$ = 11) of our marked sample failed to breed, and recruitment of young to 11 months was consistently low (i.e., 50 fawns/100 does). Over the 6 year period of 1985 to 1990, the population has fluctuated but the observed rate of change in the population is nearly zero ($r = -0.06$). These characteristics contrast with those of populations on surrounding lands where most yearling and many fawn females breed, indicating a lower density and increased biotic potential for increase.

While deer are not hunted on SARA, hunting statistics for Stillwater suggest deer born on the park have been contributing the harvest in adjacent lands. Much of SARA lies within the township of Stillwater, comprising about 22% of the total township land area. Harvests of antlered males in the town of Stillwater have always exceeded those of adjacent townships, and the region in general, by a factor of 3 to 5. We suspect that between 1960-1980, dispersal movements of young males from SARA, contributed to the higher overall buck harvest of Stillwater township. Dramatic increases in deer harvests on a regional level began to occur in the mid- to late-1970's, but by the early 1980's, resulted in the decision by the DEC to begin harvesting antlerless deer.

As in other northern latitude populations (Hoskinson and Mech 1976, Tierson et al. 1985), some deer at SARA migrate seasonally. However the timing of migration at SARA was most similar to studies conducted in more agricultural settings. Simon (1986) documented autumn migration dates similar to ours for a sample of deer utilizing a refuge in southeastern

Minnesota. Storm et al. (1989) documented migratory movements in 23% (n = 47) of marked females at Gettysburg National Military Park, while Christie and Sayre (1989) documented no migration in a small sample of marked deer at Morristown National Historical Park. In contrast, half of all fawns and 20% of yearlings dispersed from their natal ranges in an intensively farmed region of Illinois (Nixon et al. 1989). An additional 20% of non-dispersing yearling an adult females exhibited migratory behavior. Simon (1986) hypothesized that early autumn migration was a behavioral response to hunter harassment and not the onset of severe winter weather, as is the case for northern deer populations. Given that SARA probably represented one of the earliest local refuges for deer, and that hunting has always been an important autumn activity in the area, it is plausible that such movements could have developed through a similar mechanism. While female deer were not legal to harvest before 1984, we believe that the harassment level would have been sufficiently high to initiate migration patterns in deer. Spring migration to summer range is thought to be driven by the need to return to ancestral fawning areas (Simon 1986). Further, dispersal in young females in heavily farmed areas in the Midwest may be driven by a lack of suitable fawning sites (Nixon et al. 1989). This kind of plasticity in movement patterns is consistent with current theories of the adaptive significance of migration (Baker 1978).

Vegetation

The current mosaic of vegetation types on SARA reflects a history of human activities on the landscape over the past 100 years. Throughout the 19th century, the land that now comprises SARA was farmed. Deed records show that some land was donated to a local historical society for the preservation of the Battlefield before the turn of the century. By the time the State of New York began administering the site in the late 1920's, vegetation restoration was underway. At the time of its official national status in 1938, the park encompassed approximately 584 ha (1430 ac). Farming was precluded on much of the park, although mowing of some open fields continued. This process of land acquisition and subsequent release from intensive agriculture created a mosaic of old fields, orchards and woodlands whose remnants can be observed on SARA today. Changes in species composition and structure are occurring as a result of plant succession.

Regionally, land-use records reveal a steady decline in farmed acreage across Saratoga county (including the townships of Stillwater and Saratoga) between the years 1880-1970 (Dunn 1974). In 1880, approximately 88% of the total land area was in agriculture compared to 18% recorded in 1970. Since 1970, the proportion of farmland to forestland has remained steady (Ferguson and Mayer 1970, Considine and Frieswyk 1982). However, the age structure

of forests in the county has changed dramatically. Over 40% of all forest land was in the seedling/sapling stage in 1968 compared to 23% in 1980.

Impacts of Deer on Vegetation

At SARA, results of the exclosure experiment demonstrate some shifts in species composition in the herb layer over time. Ordinations among vegetation treatment plots in 1986 (i.e., after 1 growing season) indicate dissimilarity in the 10 leading dominant species within control plots. This suggests that either deer had an immediate effect on the herb layer, or that the control plots weren't really adequate between fenced and unfenced plots. We believe the latter explanation to be more accurate, which underscores the difficulty of establishing true controls in exclosure experiments. Given that scenario, the only valid comparisons would be among treatment plots and the control plot established at each fenced and unfenced location. While some differences emerged from the analysis, the overwhelming response among treatments over time was a convergence in similarity, apparently due to temporal development of vegetation. Only at the Exclosure 3 site did a divergence appear between fenced and unfenced vegetation. It is at this site that a case for a clear, deer-induced change in the composition of leading dominants can be made, which stands in contrast to most reported exclosure studies (Tilghman 1984). The relative remoteness of this exclosure site and its geographic location in the park may have predisposed this site to more intensive pressure by deer. Anecdotal observations of deer numbers in this area supports this hypothesis as does the browsing impacts on woody vegetation documented in the parkwide transect surveys.

We believe the principal impact of deer at SARA on vegetation is a general slowing of the old-field successional process. Parkwide transects indicate that browsing by deer is intense on woody stems within 2 m of the ground. Seedling density estimated using the point-centered quarter method is similar to those observed inside exclosures suggesting that these stems are persisting in the understory despite being heavily browsed by deer. However, browsing by deer is precluding their development to the sapling size class. Our data show that height growth is seldom >20 cm. The uniformity in the maximum browsing height in this stratum suggests a correlation with the average snow depth in winter; stems buried by deep snow escape browsing, while those above the snow do not. In addition, evidence from the exclosures supports the notion that browsing by deer is prolonging the time it will take for grass-forb-shrub communities to be invaded and replaced by forest. This phenomenon has been observed elsewhere (e.g., Gill and Marks 1991).

The pervasiveness of gray dogwood communities at SARA may be attributable to the browsing pressure exerted by deer. While dogwood is heavily browsed by deer, it shows an

ability to compensate by initiating new shoot growth (Austin 1992). The exclosures show that the dogwood community persists because of the inability of most tree seedlings to grow at current levels of deer browsing. Once dogwood captures a site, age data from dogwood clones suggests this stage may last 30 years or longer (Austin 1992). Stems of the clone present a physical barrier to the movement of deer, thus permitting the establishment of tree seedlings (Austin 1992). The dominance of dogwood ends when the clones begin to exceed 3 m diameter. Shade-tolerant tree species emerge from within these older clones, eventually shading out and replacing the dogwood.

Long-Term (>10 years) Projections

Vegetation -- Change in plant communities following abandonment of pastures and hayfields usually follows a consistent pattern in the eastern United States (Bard 1952, Auchmoody 1968, Pickett 1983). Annual weeds and grasses may dominate in the first few years, then goldenrods and broomsedges usually dominate for a decade or more. This may be followed by a shrub stage which may last from 15-35 years. Forest development can be expected within 30-35 years following abandonment. When fields have been abandoned as fallow cropland, hardwoods such as gray birch, paper birch, wild black cherry, quaking aspen, and Big-toothed aspen may predominate. White pine commonly develops on abandoned pastures.

The successional development of vegetation on SARA fits this pattern well. Our data show that fields are succeeding into forests, albeit at a slow rate in the presence of a high density deer population. The composition of seedling- and sapling-sized stems growing in the canopy gaps of dead trees, combined with the development of seedlings inside and outside of the exclosures offer a glimpse of what forests of SARA might look like in 100 years. Our results indicate that white ash and red maple alternate in ecological importance in the understory depending on the nature of the overstory. As seedlings, both of these species are relatively shade tolerant (U. S. Dep. Agric. 1965). With increasing size, however, white ash becomes less tolerant. We predict that in the open canopy woodlands of SARA, white ash will become the dominant overstory constituent, while in the closed canopy woodlands, red maple will assume that position. Lorimer (1984) found similar results in other northern red oak stands in the Northeast. Over time, white pine will fall from dominance in the overstory. White pines that are sapling size at present may remain an important component for 200 years or more, particularly in areas classified as younger old-fields. In addition, elms will continue to compete vigorously in the sapling size class. However, our data indicate that above a threshold diameter (dbh) of about 18 cm, mortality is very high. Like Huenneke (1983), we found little elm

regeneration (i.e., our seedling size class) in the canopy gaps of dead elms in the overstory, which contrasts with other studies of elm replacement (McBride 1973, Barnes 1976, Parker and Leopold 1983).

Deer Population — The general sequence of growth for a population of herbivores at initially low density is characterized by 3 phases: (1) initial upsurge and overshoot, (2) the "crash", and (3) the recovery to intermediate density. The irruptive sequence is the typical pattern in the growth of most ungulate populations (Leopold 1943, Caughley 1976, Caughley 1979). In an ideal ecological system, feedback between herbivores and vegetation is instantaneous: increased numbers of deer → decreased biomass of consumable vegetation in the understory → decreased numbers of deer → increased biomass of consumable vegetation. In the real world, these dynamics are obscured in a tangle of time lags associated with characteristics of both deer and plant populations, which makes predictions exceedingly difficult to make.

We believe that the future status of deer on SARA is tied to 2 factors. First, deer have access to abundant and highly nutritious broadleaf forages which are provided by large areas of open and maintained fields. Our results demonstrate that these fields represent a very important resource for deer, especially during spring and autumn. Second, the extensive shrubland communities provide abundant and adequate winter forage for deer. It is our belief that these 2 factors most influence the carrying capacity of the park. Unless one or both of these factors changes, it is unlikely that average physical condition in adult animals will change dramatically in the near term.

Will the deer population at SARA overshoot K, and then crash to low abundance? We do not believe so. Caughley (1976) and McCullough (1983) argued that the overshoot and crash phases of the irruptive sequence can be disrupted through controlled harvest at low to intermediate population density. Our data and historical regional harvest statistics indicate that population growth is frequently arrested by severe winter weather. Because the frequency of severe winters exerts a constant backdrop of mortality, a classic irruptive sequence that include a high-amplitude overshoot and subsequent crash is unlikely. The population on the park will continue to fluctuate and some deer will die every winter; however, the paradigm of deer populations overshooting K and crashing due to widespread malnutrition is not realistic for SARA.

Furthermore, it is unlikely that the imposition of antlerless harvests on lands outside of the park boundary will have a lasting impact on deer abundance on SARA. We observed a 17% decrease in annual survival rate of all females, owing largely to implementation of the antlerless permit system in 1984 and the subsequent harvest of migratory does. Because migration in young deer is learned through association with adult females, we expect that by the end of the

decade, migration behavior will be eliminated from the population. This will result in an entirely sedentary population of deer on SARA which, with the exception of dispersing animals, will be demographically independent of the population on surrounding landscape.

MANAGEMENT IMPLICATIONS

Caughley (1981) defines 4 classes of overabundance that warrant some reflection, particularly with respect to NPS management policies:

1) The animals threaten human life or livelihood.
2) The animals depress the densities of favored species.
3) The animals are too numerous for their own good.
4) In the case of large herbivorous mammals, the system of plants and animals if off its equilibrium.

He further notes that class 1 contains only conflicts with human interests, which are real enough, but not of ecological importance. Class 2 problems are purely technical. That is, the goal is to reduce the density of animals to a level (through whatever means is necessary) that allows the favored species to flourish. Overabundance as defined by class 3 is a rejection of current conditions in favor of an opinion about what is best for the animal population. This clearly represents a judgement of value. Caughley (1981) indicates that the class 4 problem is the only one to which ecology is central and about which a relatively objective and scholarly discussion is possible.

The burden of proof for any decision to remove deer rests with park managers to show that individual deer or deer populations conflict with one or more of 3 principal criteria specified in the Management Policies (U. S. Dep. Inter. 1988). First, the section on Protection of Native Animals (Chapter 4, page 5) states that animals may be removed if necessary to maintain park ecosystems, protect human health and safety, or conduct research. Second, Population Management (Chapter 4, page 6) allows for control of unnatural concentrations of native species caused by human activities, if the human activities cannot be controlled or mitigated. Third, NPS defines pests as any "animal or plant populations that interfere with the purposes of the park" (Chapter 4, page 13). Native species may be classified as a pests and may be actively managed to (1) prevent the loss of another species, (2) preserve the integrity of cultural resources, and (3) protect human safety. We infer that maintenance of park ecosystems translates to ecosystem "states" and not necessarily "processes". Consequently, all 3 of these criteria fall into the realm of value judgements.

At present, we believe no scientific rationale exists for managing the deer population at SARA. Assessing the impact of deer on the cultural resources is difficult because present planning documents at SARA are not sufficiently specific to allow development of criteria by which to judge the impact of browsing on management. For example, deer may be slowing the process of succession in the extensive shrub communities. However, no documentation available at present allows us to determine whether these shrub communities are appropriate to the historical landscape. Further, should ongoing historical studies show a need to replace shrub communities with forest, such a replacement is likely to occur in the next 50-100 years regardless of the current deer population size. In the absence of clear management objectives specifying the composition and location of plant communities necessary to interpret the historical scene, we cannot identify conflicts between deer and vegetation.

Monitoring

We believe that continued monitoring of both deer and vegetation is necessary to support a decision to manipulate deer population size in the future. We recommend night spotlighting as the best method for monitoring deer abundance at SARA. In should be understood that spotlight counts do not represent a population census method; spotlighting should be used to monitor trends in relative abundance over time. We conducted night-spotlighting surveys every week to determine the best time of year to implement a monitoring protocol. Ideally a monitoring method should be both accurate and precise. In practice, these qualities are rarely obtained in tandem, but results are best when large numbers of deer are counted. Our data suggest that field use by deer is highest in the spring immediately after snowmelt and counts during this time are likely to produce representative results. We recommend spotlight counts be conducted each year during the month of April, one count each week, and summarized as the average of 4 counts. In addition, we recommend continuation of deer drive counts so long as the exercise benefits both SARA and SUNY-CESF.

We recommend transect sampling as the most feasible and relatively inexpensive technique to monitor changes in vegetation composition and response to deer browsing. We recommend a minimum of 100 sample points dispersed across the park be sampled to ensure adequate representation. Sampling should be done once every 5 years. A crew of 2 to 3 individuals could learn to identify all plant species and complete this survey in a typical summer season. The species composition, structure and browsing impacts between time periods could be directly compared using commonly available graphical and statistical software.

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Table 1. Number of deer and recaptures by method of capture, Saratoga National Historical Park, Stillwater, NY, 1985-87.

Method	Initial	Recapture	Total
Rocket Net	72	2	74
Cap-Chur Gun	1	0	1
Stephenson Box	1	5	6
Clover Box	3	1	4
Drive Net	1	0	1
Hand	58	2	60
Grand Total	136	10	146

Table 2. Type of marking device by sex and age group for deer captured on Saratoga National Historical Park, Stillwater, NY, 1985-87.

Type of Tag	Neonates		
	Female	Male	Total
Radio Transmitter	10	11	21
Cattle Eartag	8	17	25
Unmarked	6	5	11[1]
Grand Total	24	33	57

Type of Tag	Older Deer		
	Female	Male	Total
Radio Transmitter	46	11	57
Cattle Eartag	4	5	9
Marking Collar	11	0	11
Unmarked	1	0	1
Grand Total	62	16	78

[1] Does not include one unsexed neonate.

Table 3. Sex and age of deer captured at Saratoga National Historical Park, Stillwater, NY, 1985-87.

Age Group[1]	Sex		
	Male	Female	Total
Neonate	33	24	57[2]
Fawn	14	26	40
Yearling	1	4	5
Adult	1	32	33
Grand Total	49	86	135

[1] Neonate: ≤90 days; Fawn: 4-11 mo.; Yearling: 12-23 mo; Adult: ≥24 mo.

[2] Does not include one unsexed neonate.

Table 4. Numbers, density, and population estimates derived from deer counted on three areas of Saratoga National Historical Park, Stillwater, NY, 1985-90.

Period	Area / Size (ha)	A 41	B 26	C 18	No. Deer
October '85	Number Counted	34	55	5	
	Density (#/ha)	0.84	2.09	0.28	
	Number *prorata*[1]	89	349	69	Σ = 507
September '86	Number Counted	63	22	5	
	Density (#/ha)	1.55	0.83	0.28	
	Number *prorata*[1]	164	139	69	Σ = 372
September '87	Number Counted	73	35	7	
	Density (#/ha)	1.80	1.33	0.40	
	Number *prorata*[1]	191	222	99	Σ = 512
October '88	Number Counted	56	37	0	
	Density (#/ha)	1.38	1.40	0.00	
	Number *prorata*[1]	146	234	0	Σ = 380
October '89	Number Counted	69	18	2	
	Density (#/ha)	1.70	0.68	0.11	
	Number *prorata*[1]	180	114	27	Σ = 321
October '90	Number Counted	81	24	0	
	Density (#/ha)	2.00	0.91	0.00	
	Number *prorata*[1]	212	152	0	Σ = 364

[1] Population sizes estimated by prorating sampled density proportional to the total area of the sampled cover type; values represent the estimated number of deer contributed by cover type. Area A = brush, B = mixed hardwood-softwood, and C = pure hardwood.

Table 5. Major sources of variation in 216 counts of white-tailed deer conducted at Saratoga National Historical Park, Stillwater, NY, 1985-87.

Source	DF	Sums of Squares	Mean Square	F-Value	Pr > F
Daytime					
Year	2	1.310	0.655	4.790	0.0115
Month(Year)[1]	20	16.977	0.849	6.200	0.0001
Vis(Month Year)[2]	7	2.336	0.334	2.440	0.0276
Nighttime					
Year	2	0.878	0.439	2.440	0.0925
Month(Year)	25	29.010	1.160	6.460	0.0001

[1] Read as "month within year".

[2] Read as "visibility within month and year".

Table 6. Ratios of fawns and antlered males (bucks) to a base of 100 yearling and adult females on Saratoga National Historical Park, Stillwater, NY, 1985-87.

		Number Classified (Ratio±90% CL)[1]		
Year	Month	Fawns (C_f)	Bucks (C_f)	Does (C_2)
1985	July	61	-	154
		(40±10)	-	
1985	August	95	29	181
		(53±10)	(16±5)	
1985	September	127	18	181
		(70±13)	(10±4)	
1985	October	315	35	345
		(91±12)	(10±3)	
1985	November	509	72	651
		(78±8)	(11±2)	
1985	December	205	8	247
		(83±13)	(3±2)	
1986	January	253	1	191[2]
		(110±26)	-	
1986	March	123	-	142[2]
		(87±18)	-	
1986	April	168	-	261[2]
		(64±10)	-	
1986	May	251	11	458
		(55±7)	(2±1)	
1986	August	110	28	205
		(54±10)	(14±5)	
1986	September	138	25	240
		(58±10)	(10±3)	

Table 6. continued.

Year	Month	Number Classified (Ratio±90% CL)[1] Fawns (C_1)	Bucks (C_1)	Does (C_2)
1986	October	224	42	346
		(65±9)	(12±3)	
1986	November	204	38	321
		(64±9)	(12±3)	
1986	December	337	23	452
		(75±9)	(5±2)	
1987	January	54	1	72[2]
		(72±22)	-	
1987	April	230	-	446[2]
		(52±7)	-	
1987	May	170	14	331
		(51±8)	(4±2)	
1987	June	10	23	163
		(6±3)	(14±5)	
1987	July	10	6	25
		(40±25)	(24±18)	
1987	September	37	5	56
		(66±23)	(9±3)	
1987	October	174	15	235
		(74±12)	(6±5)	
1987	November	113	33	169
		(67±7)	(20±6)	

[1] $CL_{90\%} = ((1.65*(Ratio+100))/10)*SQRT(Ratio/(C_1+C_2))$.

[2] C_2 = classified yearling and adult animals of both sexes.

Table 7. Reproductive rates for female white-tailed deer on Saratoga National Historical Park, Stillwater, NY, 1985-87.

Age Group	% of Female Population[1]	% of Group Breeding		Fetuses/ Female[3]	Reproductive Rate[2]	Reproductive Rate[3]
Adult	63	100[2]	100[3]	2.00	2.00	2.00
Yearling	14	64	42	1.00	0.64	0.42
Fawn	23	2	3	1.00	0.02	0.03

[1] Estimated from October population ratios; number of deer classified was 695, 612, and 424 for 1985, 1986, and 1987, respectively.

[2] Estimated from marked sample of female deer.

[3] Estimated from a small sample of reproductive tracts; n = 4 for adults, 12 for yearlings, and 34 for fawns.

Table 8. Morphological characteristics and index of condition[1] for white-tailed deer examined during Spring (March-May) on Saratoga National Historical Park, Stillwater, NY, 1985-87.

Sex	Age Group	Variable	Sample Size	Mean	Std. Dev.	Minimum	Maximum
Female	Fawn	Girth	17	644	47	565	725
		Hindfoot	20	421	20	382	455
		Condition	16	0.183	0.030	0.123	0.257
	Yearling	Girth	7	705	238	179	870
		Hindfoot	7	468	7	455	477
		Condition	7	0.136	0.250	-0.426	0.282
	Adult	Girth	10	829	53	740	880
		Hindfoot	12	473	17	436	498
		Condition	10	0.242	0.032	0.188	0.280
Male	Fawn	Girth	16	677	56	568	765
		Hindfoot	23	441	20	407	478
		Condition	16	0.177	0.026	0.108	0.216
	Yearling	Girth	-	-	-	-	-
		Hindfoot	-	-	-	-	-
		Condition	-	-	-	-	-
	Adult	Girth	3	829	91	738	920
		Hindfoot	3	507	25	492	536
		Condition	3	0.212	0.032	0.175	0.235

[1] Condition = $\log_{10}(\text{Girth}) - \log_{10}(\text{Hindfoot})$.

Table 9. Morphological characteristics and index of condition[1] for white-tailed deer examined during Summer (June-August) on Saratoga National Historical Park, Stillwater, NY, 1985-87.

Sex	Age Group	Variable	Sample Size	Mean	Std. Dev.	Minimum	Maximum
Female	Fawn	Girth	-	-	-	-	-
		Hindfoot	-	-	-	-	-
		Condition	-	-	-	-	-
	Yearling	Girth	1	688	-	688	688
		Hindfoot	1	448	-	448	448
		Condition	1	0.186	-	0.186	0.186
	Adult	Girth	1	840	-	840	840
		Hindfoot	1	470	-	470	470
		Condition	1	0.252	-	0.252	0.252
Male	Fawn	Girth	-	-	-	-	-
		Hindfoot	-	-	-	-	-
		Condition	-	-	-	-	-
	Yearling	Girth	1	736	-	736	736
		Hindfoot	2	466	13	457	475
		Condition	1	0.207	-	0.207	0.207
	Adult	Girth	-	-	-	-	-
		Hindfoot	-	-	-	-	-
		Condition	-	-	-	-	-

[1] Condition = $\log_{10}$(Girth) - $\log_{10}$(Hindfoot).

Table 10. Morphological characteristics and index of condition[1] for white-tailed deer examined during Autumn (September-November) on Saratoga National Historical Park, Stillwater, NY, 1985-87.

Sex	Age Group	Variable	Sample Size	Mean	Std. Dev.	Minimum	Maximum
Female	Fawn	Girth	6	699	66	613	801
		Hindfoot	8	431	20	411	471
		Condition	6	0.208	0.023	0.174	0.232
	Yearling	Girth	5	876	19	855	898
		Hindfoot	7	460	19	419	477
		Condition	5	0.273	0.013	0.260	0.295
	Adult	Girth	28	886	48	808	989
		Hindfoot	29	474	15	443	503
		Condition	28	0.271	0.022	0.233	0.319
Male	Fawn	Girth	10	725	36	673	775
		Hindfoot	15	429	17	393	459
		Condition	10	0.223	0.019	0.194	0.257
	Yearling	Girth	88	875	70	509	975
		Hindfoot	95	490	15	457	530
		Condition	86	0.250	0.042	0.012	0.305
	Adult	Girth	45	962	55	837	1113
		Hindfoot	48	503	20	438	537
		Condition	44	0.281	0.020	0.246	0.343

[1] Condition = $\log_{10}(\text{Girth}) - \log_{10}(\text{Hindfoot})$.

Table 11. Morphological characteristics and index of condition[1] for white-tailed deer examined during Winter (December-February) on Saratoga National Historical Park, Stillwater, NY, 1985-87.

Sex	Age Group	Variable	Sample Size	Mean	Std. Dev.	Minimum	Maximum
Female	Fawn	Girth	27	672	46	550	755
		Hindfoot	34	412	16	375	442
		Condition	26	0.209	0.021	0.166	0.257
	Yearling	Girth	6	819	51	749	897
		Hindfoot	10	463	20	435	500
		Condition	5	0.250	0.034	0.205	0.294
	Adult	Girth	39	878	52	785	988
		Hindfoot	39	475	17	435	545
		Condition	39	0.267	0.021	0.210	0.318
Male	Fawn	Girth	17	708	59	598	818
		Hindfoot	21	432	19	396	462
		Condition	17	0.209	0.033	0.151	0.275
	Yearling	Girth	4	845	31	812	873
		Hindfoot	4	484	25	465	519
		Condition	2	0.225	0.001	0.225	0.226
	Adult	Girth	6	932	50	869	983
		Hindfoot	5	507	15	492	528
		Condition	4	0.269	0.015	0.247	0.280

[1] Condition = $\log_{10}$(Girth) - $\log_{10}$(Hindfoot).

Table 12. Sources of variation in white-tailed deer condition on Saratoga National Historical Park, Stillwater, NY, 1985-87.

Source	DF	Sums of Squares	Mean Square	F-Value	Pr > F
Condition (n = 327)					
Season	3	0.101	0.034	16.110	0.0001
Age Group(Season)[1]	7	0.119	0.017	8.080	0.0001
Sex(Age Group Season)[2]	9	0.008	0.001	0.450	0.9070

[1] Read as "age group within season".

[2] Read as "sex within age group and season".

Source	DF	Sums of Squares	Mean Square	F-Value	Pr > F
Log_{10} Girth (n = 337)					
Season	3	0.113	0.038	17.410	0.0001
Age Group(Season)[1]	7	0.452	0.065	29.940	0.0001
Sex(Age Group Season)[2]	9	0.034	0.004	1.750	0.0776

[1] Read as "age group within season".

[2] Read as "sex within age group and season".

Source	DF	Sums of Squares	Mean Square	F-Value	Pr > F
Log_{10} Hindfoot (n = 384)					
Season	3	0.000	0.000	0.330	0.8006
Age Group(Season)[1]	7	0.146	0.021	76.960	0.0001
Sex(Age Group Season)[2]	9	0.033	0.004	13.610	0.0001

[1] Read as "age group within season".

[2] Read as "sex within age group and season".

Table 13. Survival estimates for female white-tailed deer captured on Saratoga National Historical Park, Stillwater, NY, 1985-87.

Date (t)	Days In Interval	No. At Risk	No. Dying	No. Censored	No. Added	Survival $\hat{S}$	Variance[1] $var(\hat{S}_t)$
841215 - 850410	59	18	1	0	0	0.94	0.0029
850411 - 851001	87	17	1	0	0	0.89	0.0207
851002 - 851214	37	16	0	0	0	0.89	0.0494
851215 - 860410	59	16	6	3	31	0.56	0.1372
860411 - 861001	87	38	2	0	0	0.53	0.0863
861002 - 861214	37	36	5	0	2	0.45	0.1123
861215 - 870410	59	33	2	3	11	0.43	0.1545
870411 - 871001	87	39	1	0	0	0.41	0.1652
871002 - 871214	37	38	7	1	0	0.34	0.1615
871215 - 880410	59	30	1	20	0	0.33	0.2400

[1] Approximate 95% confidence intervals can be obtained by: $\hat{S}_t \pm 1.96[var(\hat{S}_t)]^{1/2}$.

Table 14. Marginal survival estimates for female white-tailed deer captured on Saratoga National Historical Park, Stillwater, NY, 1985-87. All non-hunting agents of mortality are treated as censored observations.

Date (t)	Days In Interval	No. At Risk	No. Dying	No. Censored	No. Added	Survival $\hat{S}$	Variance[1] $var(\hat{S}_t)$
841215 - 850410	59	18	0	1	0	1.00	0.0000
850411 - 851001	87	17	1	0	0	0.94	0.0123
851002 - 851214	37	16	0	0	0	0.94	0.0293
851215 - 860410	59	16	0	9	31	0.94	0.0521
860411 - 861001	87	38	0	2	0	0.94	0.0343
861002 - 861214	37	36	5	0	2	0.81	0.1245
861215 - 870410	59	33	1	4	11	0.79	0.1964
870411 - 871001	87	39	1	0	0	0.77	0.2254
871002 - 871214	37	38	7	1	0	0.62	0.3122
871215 - 880410	59	30	0	21	0	0.62	0.4882

[1] Approximate 95% confidence intervals can be obtained by: $\hat{S}_t \pm 1.96[var(\hat{S}_t)]^{1/2}$.

Table 15. Survival estimates for male white-tailed deer captured on Saratoga National Historical Park, Stillwater, NY, 1985-87.

Date (t)	Days In Interval	No. At Risk	No. Dying	No. Censored	No. Added	Survival $\hat{S}$	Variance[1] $var(\hat{S}_t)$
841215 - 850410	59	6	0	0	0	1.00	0.0000
850411 - 851001	87	6	0	0	0	1.00	0.0000
851002 - 851214	37	6	3	0	0	0.50	0.1875
851215 - 860410	59	3	1	1	8	0.33	0.3950
860411 - 861001	87	9	0	0	0	0.33	0.2057
861002 - 861214	37	9	8	0	0	0.04	0.0053
861215 - 870410	59	1	0	0	2	0.04	0.0646
870411 - 871001	87	3	0	1	0	0.04	0.0281
871002 - 871214	37	2	1	1	0	0.02	0.0136
871215 - 880410	59	0	0	0	0	0.00	0.0000

[1] Approximate 95% confidence intervals can be obtained by: $\hat{S}_t \pm 1.96[var(\hat{S}_t)]^{1/2}$.

Table 16. Marginal survival estimates for male white-tailed deer captured on Saratoga National Historical Park, Stillwater, NY, 1985-87. All non-hunting agents of mortality are treated as censored observations.

Date (t)	Days In Interval	No. At Risk	No. Dying	No. Censored	No. Added	Survival $\hat{S}$	Variance[1] $var(\hat{S}_t)$
841215 - 850410	59	6	0	0	0	1.00	0.0000
850411 - 851001	87	6	0	0	0	1.00	0.0000
851002 - 851214	37	6	3	0	0	0.50	0.1875
851215 - 860410	59	3	0	2	8	0.50	0.6667
860411 - 861001	87	9	0	0	0	0.50	0.3472
861002 - 861214	37	9	8	0	0	0.06	0.0117
861215 - 870410	59	1	0	0	2	0.06	0.1431
870411 - 871001	87	3	0	1	0	0.06	0.0623
871002 - 871214	37	2	1	1	0	0.03	0.0304
871215 - 880410	59	0	0	0	0	0.00	0.0000

[1] Approximate 95% confidence intervals can be obtained by: $\hat{S}_t \pm 1.96[var(\hat{S}_t)]^{1/2}$.

Table 17. Ecological characteristics of the closed-canopy woodland of Saratoga National Historical Park, Stillwater, NY, 1987. Number of individuals is 172.

Species[1]	Relative Frequency (RF)	Relative Dominance (RDo)	Relative Density (RD)	Variance of RD[2]	Relative Importance (IV)
White Pine	20.91	42.49	27.33	0.00242	90.73
Red Maple	11.82	7.63	12.21	0.00111	31.66
Elm	9.09	6.24	8.72	0.00040	24.05
Northern Red Oak	7.27	4.98	4.65	0.00022	16.90
Big-toothed Aspen	4.54	5.70	4.07	0.00033	14.32
Eastern Hop-hornbeam	6.36	1.47	5.81	0.00053	13.65
Quaking Aspen	4.54	3.84	4.65	0.00042	13.04
Sugar Maple	4.54	3.08	4.65	0.00049	12.28
American Beech	4.54	2.01	4.07	0.00040	10.63
Wild Black Cherry	4.54	1.96	4.07	0.00040	10.57

[1]Associated Species: Black Willow, Eastern Hemlock, White Ash, Gray Birch, Yellow Birch, Common Buckthorn, White Oak, Shagbark Hickory, American Basswood, Hawthorn, Black Oak, Swamp White Oak, Box Elder, Apple.

[2] Heyting (1968).

Table 18. Ecological characteristics of the open woodlands of Saratoga National Historical Park, Stillwater, NY, 1987. Number of individuals is 288.

Species[1]	Relative Frequency (RF)	Relative Dominance (RDo)	Relative Density (RD)	Variance of RD[2]	Relative Importance (IV)
White Pine	25.44	40.75	34.03	0.01194	100.22
Elm	30.77	30.09	28.82	0.00056	90.28
Wild Black Cherry	10.06	4.47	9.03	0.00042	23.56
White Ash	8.28	2.68	6.25	0.00026	17.21
Red Maple	4.14	7.50	4.51	0.00010	16.15
Quaking Aspen	2.37	1.98	2.43	0.00015	6.78
Sugar Maple	1.18	4.44	1.04	0.00006	6.67
Northern Red Oak	2.37	0.95	2.08	0.00011	5.40
Swamp White Oak	1.77	1.74	1.74	0.00010	5.25
Gray Birch	2.37	0.64	1.39	0.00005	4.40

[1] Associated Species: Hawthorn, Apple, Common Buckthorn, Black Oak, Black Locust, Eastern Hop-hornbeam, Black Walnut, Big-toothed Aspen, Box Elder, White Oak, American Beach, Green Ash, Shagbark Hickory, Pin Cherry.

[2] Heyting (1968).

Table 19. Characteristics of select ($\underline{n}$ ≥10) tree-sized woody stems on Saratoga National Historical Park, Stillwater, NY, 1987.

Species	% Browsed	% Living	Height (m)	HTH[1] (m)
White Pine	35.17	95.90	14.62	2.17
Wild Black Cherry	9.09	98.20	13.20	1.35
Northern Red Oak	7.14	100.00	18.00	0.11
Quaking Aspen	6.67	73.30	18.10	0.12
White Ash	4.35	87.00	13.80	0.07
Elm	4.08	68.40	12.30	1.57
Eastern Hop-hornbeam	0.00	91.70	14.90	0.00
Red Maple	0.00	100.00	18.20	0.00
Sugar Maple	0.00	100.00	17.82	0.00

[1] HTH = height to highest browsed stem.

Table 20. Characteristics of select ($\underline{n}$ ≥10) sapling-sized woody stems on Saratoga National Historical Park, Stillwater, NY, 1987.

Species	% Browsed	% Living	Height (m)	HTH[1] (m)
American Beech	70.00	80.00	5.31	0.90
Common Buckthorn	66.67	97.10	4.52	1.33
Eastern Hop-hornbeam	40.00	100.00	6.22	0.81
White Pine	40.00	81.50	6.71	2.04
Hawthorn	38.71	90.00	4.72	0.53
White Ash	31.25	85.90	5.13	1.21
Wild Black Cherry	29.63	92.59	5.16	0.43
Hornbeam	25.00	100.00	6.22	0.35
Witchhazel	18.18	90.91	3.85	0.21
Elm	10.29	85.30	6.08	1.38
Sugar Maple	8.33	91.67	6.31	0.03
Red Maple	4.55	95.46	10.12	0.07

[1] HTH = height to highest browsed stem.

Table 21. Characteristics of select ($\underline{n}$ ≥10) seedling-sized woody stems on Saratoga National Historical Park, Stillwater, NY, 1987.

Species	% Browsed	% Living	Height (m)	HTH[1] (m)
American Beech	66.67	91.67	0.27	0.21
Quaking Aspen	66.67	100.00	0.23	0.12
Elm	42.86	100.00	0.25	0.17
Wild Black Cherry	38.33	100.00	0.22	0.29
Common Buckthorn	37.50	100.00	0.23	0.32
Eastern Hop-hornbeam	30.00	100.00	0.18	0.08
Northern Red Oak	28.57	100.00	0.19	0.04
White Ash	28.26	99.30	0.25	0.29
Sugar Maple	21.43	100.00	0.12	0.02
Red Maple	17.65	100.00	0.14	0.21

[1] HTH = height to highest browsed stem.

Table 22. Characteristics of select ($n \geq 10$) shrubs on Saratoga National Historical Park, Stillwater, NY, 1987.

Species	% Browsed	% Living	Height (m)	HTH[1] (m)
Nannyberry	52.63	100.00	0.40	0.25
Gray Dogwood[2]	56.16	97.80	0.43	0.42
Arrowwood	41.30	100.00	0.32	0.13
Tartarian Honeysuckle	38.46	100.00	0.41	0.45
Maple-leafed Viburnum	36.11	100.00	0.28	0.12

[1] HTH = height to highest browsed stem.

[2] Applies to single, rooted stems and not clumps.

Table 23. Numbers and species of tree seedlings regenerating in fenced and unfenced plots of 3 old field sites at Saratoga National Historical Park, Stillwater, NY, 1990.

Species	Number
White Ash	157
Red Maple	100
Common Buckthorn	89
Elm	89
Hawthorn	81
Wild Black Cherry	62
Wild Plum	47
White Pine	20
Serviceberry	19
Apple	7
Quaking Aspen	2
Northern Red Oak	2
Black Willow	1
Pignut Hickory	1
Black Oak	1
White Oak	1

Table 24. Ecological characteristics of overstory species where dead elms comprised ≥25% of stems tallied on Saratoga National Historical Park, Stillwater, NY, 1987. Number of individuals is 96.

Species	Relative Frequency (RF)	Relative Dominance (RDo)	Relative Density (RD)	Variance of RD[1]	Relative Importance (IV)
Elm	42.86	50.58	52.08	0.00149	145.51
White Pine	19.05	21.34	18.75	0.00201	59.13
Wild Black Cherry	7.94	2.72	7.29	0.00097	17.94
White Ash	7.94	1.91	6.25	0.00071	16.10
Black Willow	1.59	11.89	1.04	0.00010	14.52
Sugar Maple	1.59	7.89	1.04	0.00010	10.52
Apple	4.76	0.92	3.13	0.00028	8.80
Common Buckthorn	3.17	0.49	2.08	0.00020	5.75
Black Locust	1.59	0.44	2.08	0.00042	4.11
Black Walnut	1.59	0.63	1.04	0.00010	3.26
Red Maple	1.59	0.36	1.04	0.00010	2.99
Green Ash	1.59	0.22	1.04	0.00010	2.85
Hawthorn	1.59	0.22	1.04	0.00010	2.85
Swamp White Oak	1.59	0.22	1.04	0.00010	2.83
Northern Red Oak	1.59	0.22	1.04	0.00010	2.82

[1] Heyting (1968).

Table 25. Ecological characteristics of sapling-sized species where dead elms comprised ≥25% of stems tallied in the overstory on Saratoga National Historical Park, Stillwater, NY, 1987. Number of individuals is 96.

Species	Relative Frequency (RF)	Relative Dominance (RDo)	Relative Density (RD)	Variance of RD[1]	Relative Importance (IV)
Elm	32.73	49.99	36.46	0.00169	119.18
Common Buckthorn	21.82	16.69	23.96	0.00173	62.47
White Ash	12.73	10.13	10.42	0.00128	33.27
White Pine	9.09	10.52	11.46	0.00119	31.07
Wild Black Cherry	9.09	6.96	7.29	0.00119	23.35
Hawthorn	9.09	2.99	6.25	0.00071	18.33
Hornbeam	3.64	2.24	3.13	0.00050	9.00
Serviceberry	1.82	0.47	1.04	0.00010	3.33

[1] Heyting (1968).

Table 26. Ecological characteristics of seedling-sized species where dead elms comprised ≥25% of stems tallied in the overstory on Saratoga National Historical Park, Stillwater, NY, 1987. Number of individuals is 96.

Species	Relative Frequency (RF)	Relative Dominance (RDo)	Relative Density (RD)	Variance of RD[1]	Relative Importance (IV)
White Ash	30.43	0.00	36.96	0.00564	67.39
Common Buckthorn	23.91	0.00	25.00	0.00224	48.91
Wild Black Cherry	13.04	0.00	15.22	0.00171	28.26
Red Maple	8.70	0.00	9.78	0.00077	18.48
Elm	8.69	0.00	4.35	0.00019	13.04
Hawthorn	6.52	0.00	3.26	0.00031	9.78
Northern Red Oak	2.17	0.00	2.17	0.00045	4.35
Hornbeam	2.17	0.00	1.09	0.00011	3.26
Quaking Aspen	2.17	0.00	1.09	0.00011	3.26
Apple	2.17	0.00	1.09	0.00011	3.26

[1] Heyting (1968).

Table 27. Ecological characteristics of the overstory where dead species other than elms comprised ≥25% of stems tallied on Saratoga National Historical Park, Stillwater, NY, 1987. Number of individuals is 60.

Species	Relative Frequency (RF)	Relative Dominance (RDo)	Relative Density (RD)	Variance of RD[1]	Relative Importance (IV)
White Pine	20.93	39.08	26.67	0.00165	86.68
Quaking Aspen	11.63	17.34	15.00	0.00322	43.97
Red Maple	13.95	6.47	10.00	0.00100	30.42
Northern Red Oak	11.63	5.38	8.33	0.00093	25.34
Gray Birch	11.63	3.72	8.33	0.00093	23.68
Big-toothed Aspen	4.65	12.47	5.00	0.00122	22.12
American Beech	6.98	2.63	5.00	0.00067	14.61
Wild Black Cherry	4.65	4.11	5.00	0.00122	13.76
Eastern Hop-hornbeam	4.65	1.90	5.00	0.00122	11.55
Hawthorn	2.33	2.79	5.00	0.00233	10.11
White Ash	2.33	1.09	3.33	0.00104	6.75
Sugar Maple	2.33	1.78	1.67	0.00026	5.77
Box Elder	2.33	1.23	1.67	0.00026	5.22

[1] Heyting (1968).

Table 28. Ecological characteristics of sapling-sized species where dead trees other than elms comprised ≥25% of stems tallied in the overstory on Saratoga National Historical Park, Stillwater, NY, 1987. Number of individuals is 60.

Species	Relative Frequency (RF)	Relative Dominance (RDo)	Relative Density (RD)	Variance of RD[1]	Relative Importance (IV)
Red Maple	21.62	21.74	18.33	0.00248	61.69
White Ash	16.22	11.01	20.00	0.00150	47.22
White Pine	5.40	14.86	8.33	0.00009	28.60
Wild Black Cherry	8.11	6.75	8.33	0.00204	23.19
Gray Birch	5.40	8.13	6.67	0.00248	20.20
Northern Red Oak	5.40	6.95	5.00	0.00122	17.35
Sugar Maple	5.40	5.12	6.67	0.00248	17.19
Hawthorn	5.40	6.01	5.00	0.00122	16.41
Elm	5.40	6.06	3.34	0.00026	14.80
Eastern Hop-hornbeam	5.40	3.37	5.00	0.00122	13.77
American Beech	2.70	7.61	3.33	0.00104	13.65
Hornbeam	5.40	1.82	5.00	0.00122	12.23
Witchhazel	5.40	0.13	3.33	0.00048	8.86
Serviceberry	2.70	0.45	1.67	0.00026	4.82

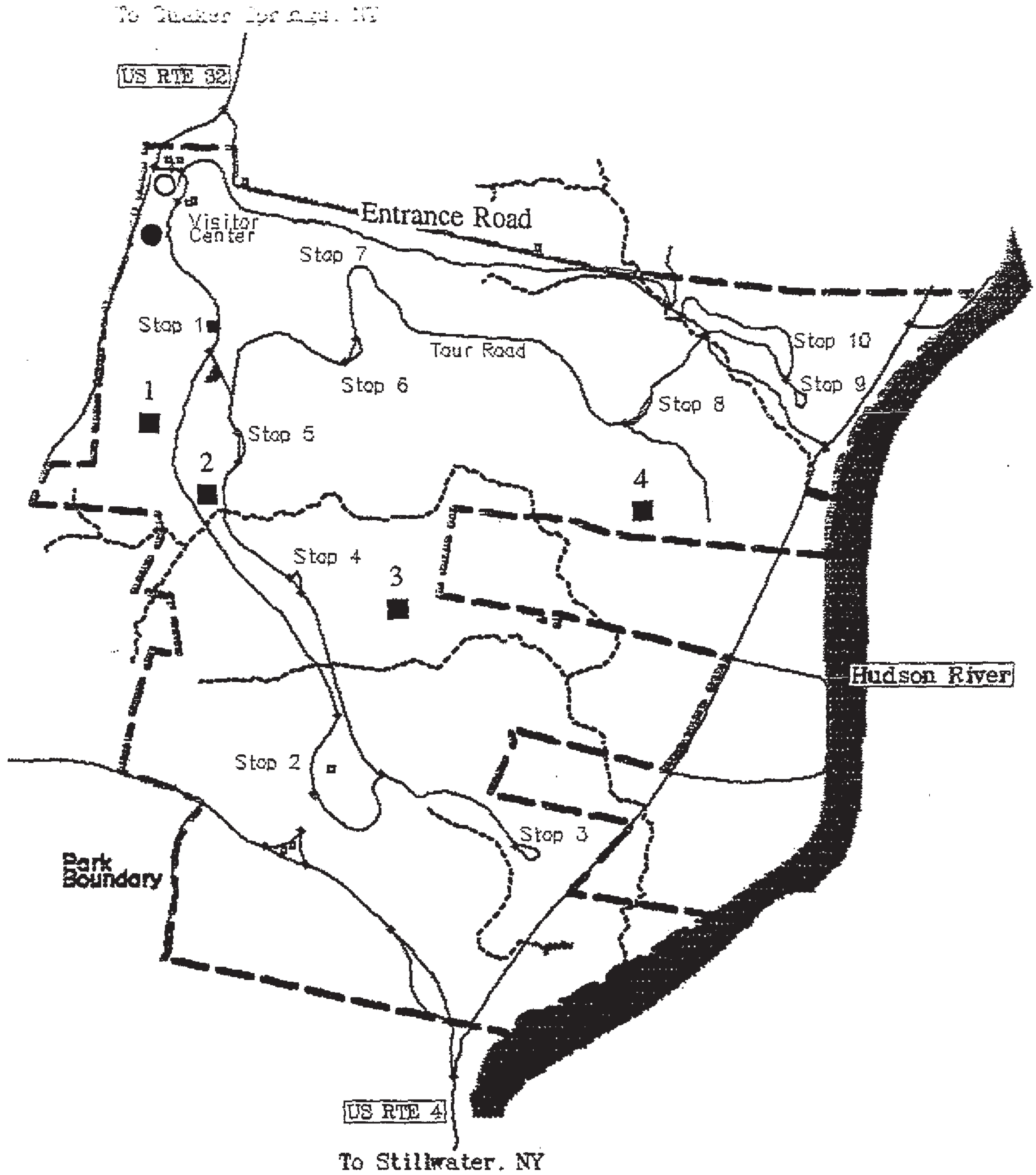
[1] Heyting (1968).

Table 29. Ecological characteristics of seedling-sized species where dead trees other than elms comprised ≥25% of stems tallied in the overstory on Saratoga National Historical Park, Stillwater, NY, 1987. Number of individuals is 60.

Species	Relative Frequency (RF)	Relative Dominance (RDo)	Relative Density (RD)	Variance of RD[1]	Relative Importance (IV)
Red Maple	21.62	0.00	26.67	0.00220	48.29
White Ash	21.62	0.00	23.33	0.00165	44.95
Wild Black Cherry	13.51	0.00	11.67	0.00215	25.18
American Beech	5.40	0.00	6.67	0.00248	12.07
Sugar Maple	5.40	0.00	3.33	0.00048	8.74
Shagbark Hickory	5.40	0.00	3.33	0.00048	8.74
Quaking Aspen	2.70	0.00	5.00	0.00233	7.70
Eastern Hop-hornbeam	2.70	0.00	5.00	0.00233	7.70
White Pine	2.70	0.00	3.33	0.00104	6.04
Northern Red Oak	2.70	0.00	1.67	0.00026	4.37
Serviceberry	2.70	0.00	1.67	0.00026	4.37
Bitternut Hickory	2.70	0.00	1.67	0.00026	4.37
Hornbeam	2.70	0.00	1.67	0.00026	4.37
Big-toothed Aspen	2.70	0.00	1.67	0.00026	4.37
Common Buckthorn	2.70	0.00	1.67	0.00026	4.37

[1] Heyting (1968).

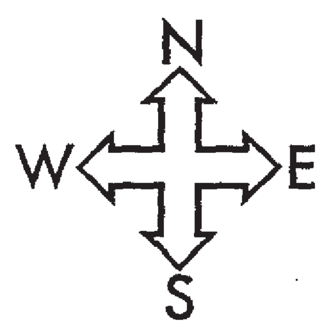
Figure 1. Saratoga National Historical Park, Stillwater, NY.



● Weather Station 1

○ Weather Station 2

■ Deer Exclosure

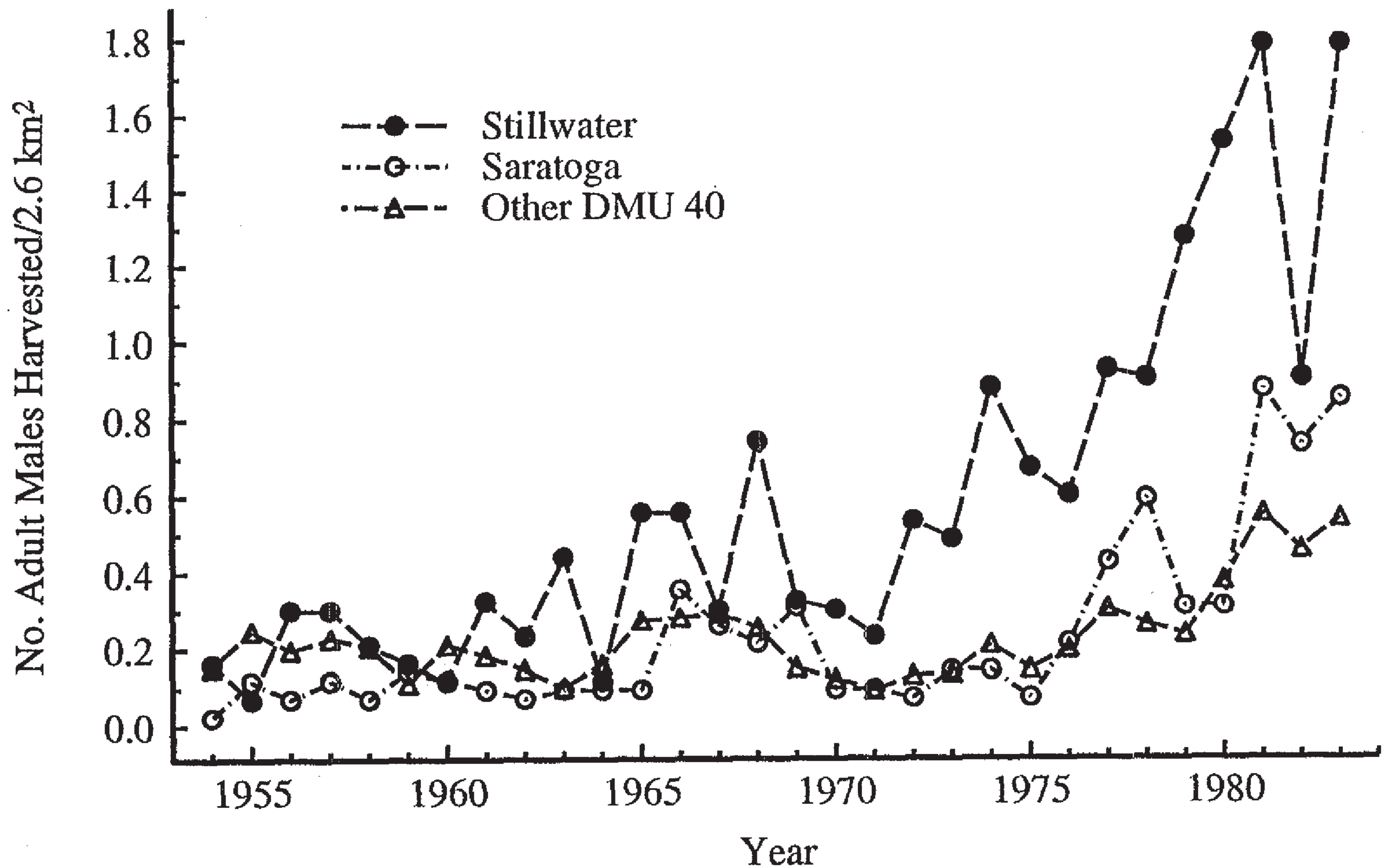


Scale = 1:35,000

Figure 2. Distribution of major vegetation cover types on Saratoga National Historical Park, Stillwater, NY.

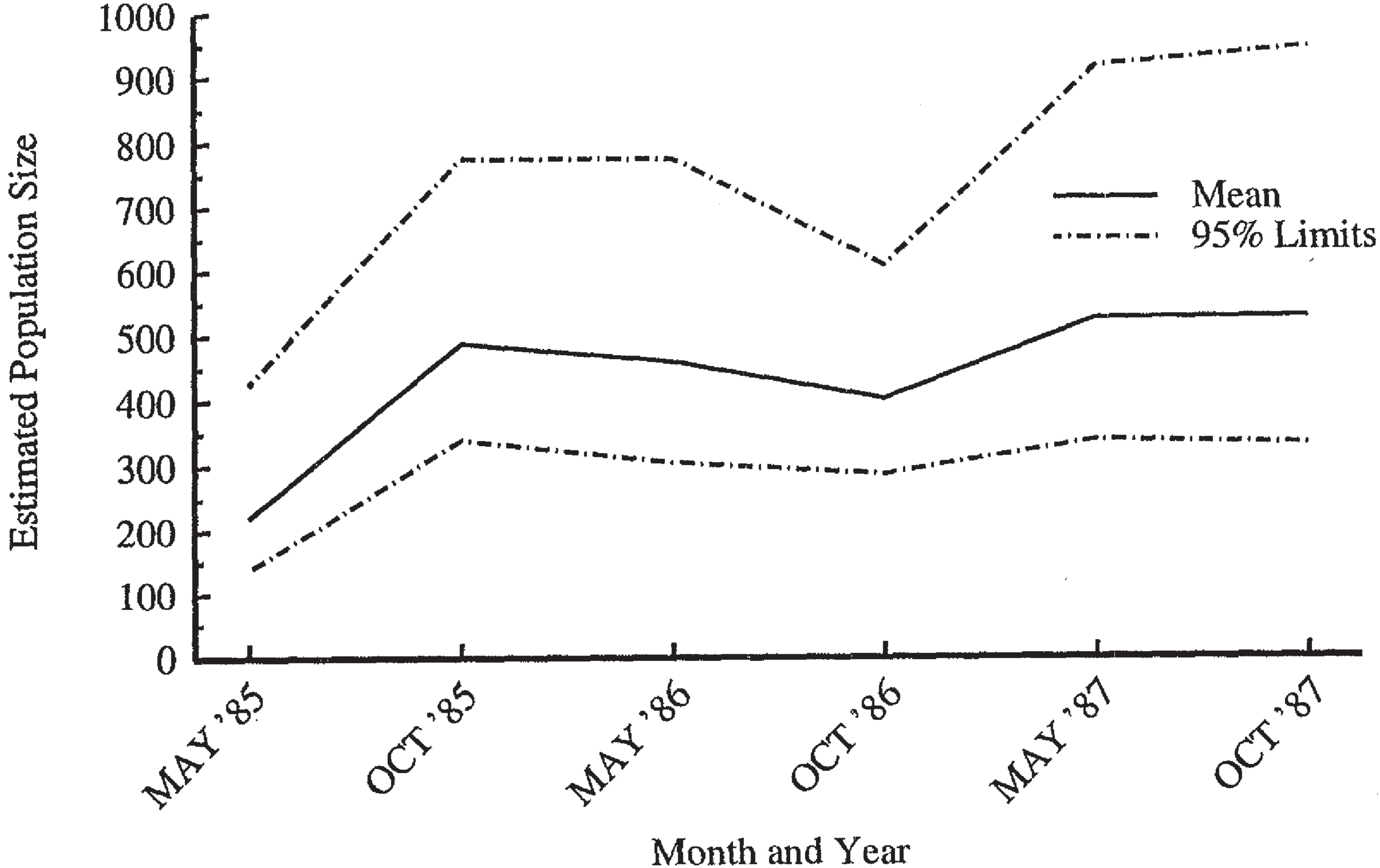

Visitor Center
Hudson River
Park Boundary
Managed Fields
Brushland
Woodland
Open Water
Developed
N
W
E
S
Scale = 1:35,000

Figure 3. Reported adult male white-tailed deer harvest for Stillwater, Saratoga and other Deer Management Unit 40 townships, 1954-83.



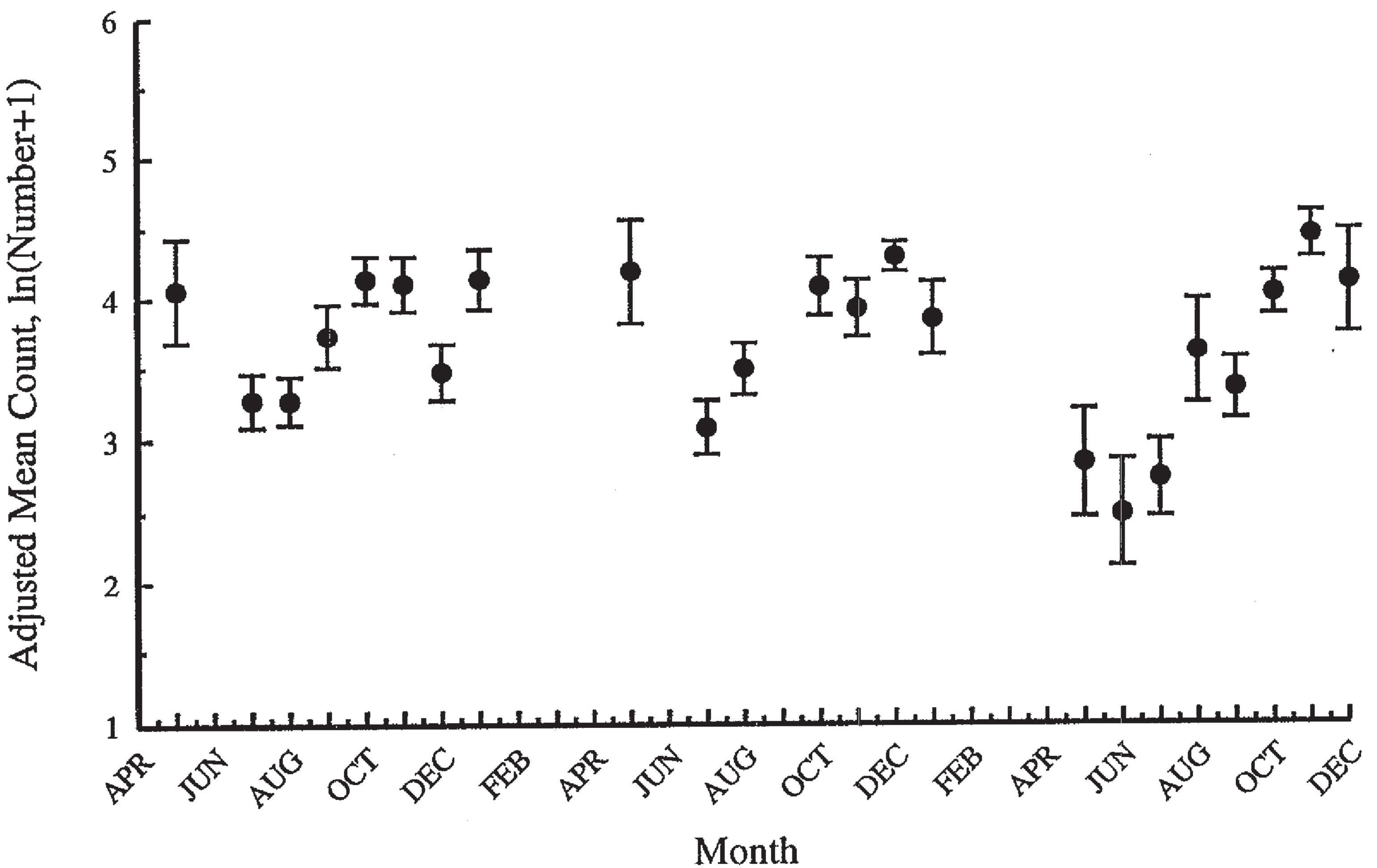
Stillwater
Saratoga
Other DMU 40
No. Adult Males Harvested/2.6 km²
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
1955
1960
1965
1970
1975
1980
Year

Figure 4. Mark-resight estimates of white-tailed deer population size on Saratoga National Historical Park, Stillwater, NY, 1985-87.



Estimated Population Size
1000
900
800
700
600
500
400
300
200
100
0
Mean
95% Limits
MAY '85
OCT '85
MAY '86
OCT '86
MAY '87
OCT '87
Month and Year

Figure 5. Adjusted, mean monthly daytime counts of white-tailed deer along a 17.1 km route on Saratoga National Historical Park, Stillwater, NY, 1985-87. Error bars represent ± 1 standard error.



Adjusted Mean Count, ln(Number+1)
6
5
4
3
2
1
APR
JUN
AUG
OCT
DEC
FEB
APR
JUN
AUG
OCT
DEC
FEB
APR
JUN
AUG
OCT
DEC
Month

Figure 6. Adjusted, mean monthly nighttime counts of white-tailed deer along a 17.1 km route on Saratoga National Historical Park, Stillwater, NY, 1985-87. Error bars represent ± 1 standard error.

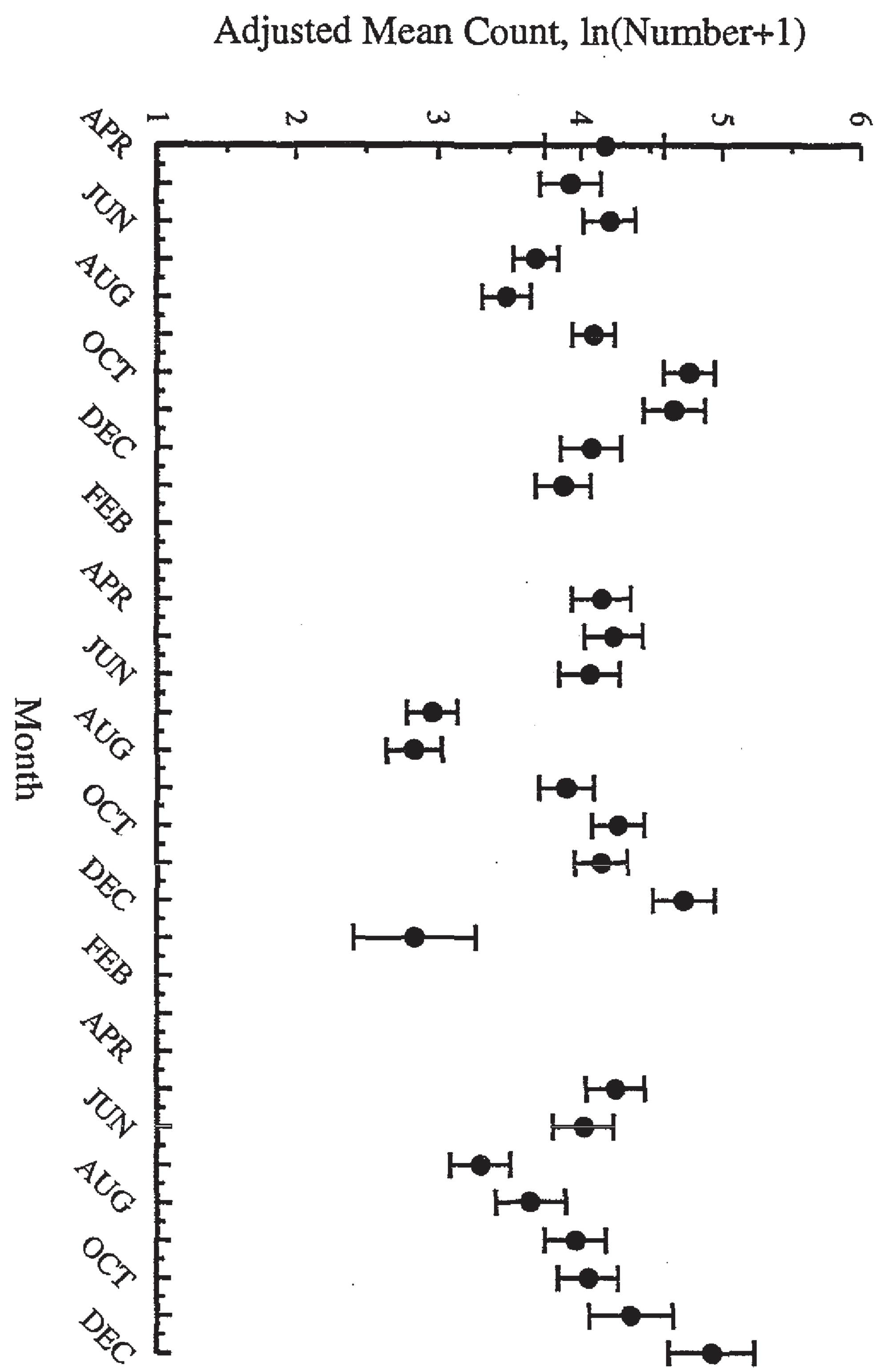
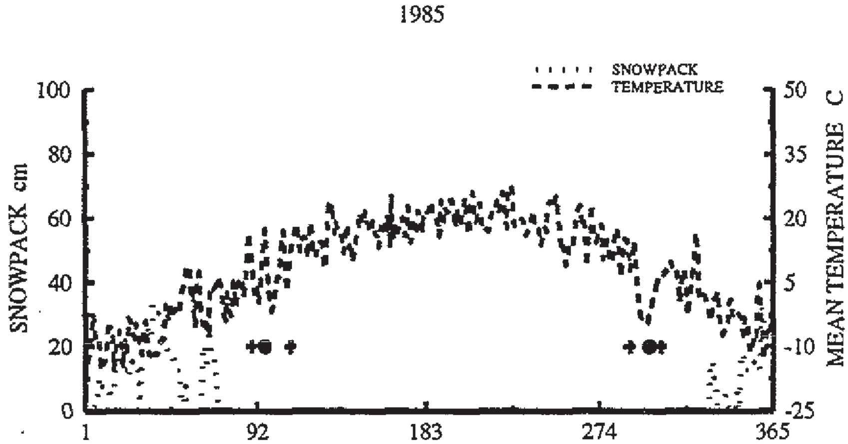
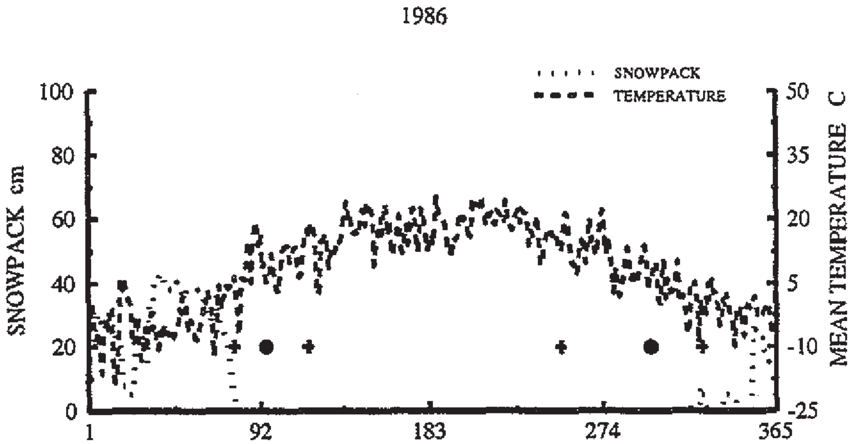

Adjusted Mean Count, ln(Number+1)
1
2
3
4
5
6
Month
APR
JUN
AUG
OCT
DEC
FEB
APR
JUN
AUG
OCT
DEC
FEB
APR
JUN
AUG
OCT
DEC

Figure 7. Median migration dates (+ indicates extrema) in Julian day equivalents for a sample of radio-collared white-tailed deer on Saratoga National Historical Park, Stillwater, NY, 1985-87.


1985
SNOWPACK
TEMPERATURE
SNOWPACK cm
MEAN TEMPERATURE C
100
80
60
40
20
0
50
35
20
5
-10
-25
1
92
183
274
365


1986
SNOWPACK
TEMPERATURE
SNOWPACK cm
MEAN TEMPERATURE C
100
80
60
40
20
0
50
35
20
5
-10
-25
1
92
183
274
365

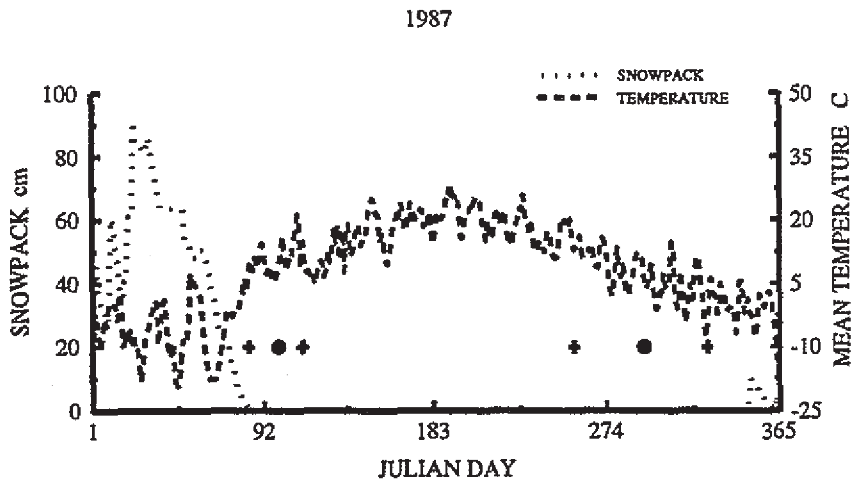

1987
SNOWPACK
TEMPERATURE
SNOWPACK cm
MEAN TEMPERATURE C
100
80
60
40
20
0
50
35
20
5
-10
-25
1
92
183
274
365
JULIAN DAY

Figure 8. Seasonal condition (ages pooled) of white-tailed deer on Saratoga National Historical Park, Stillwater, NY, 1985-87. Error bars represent 1 standard error.

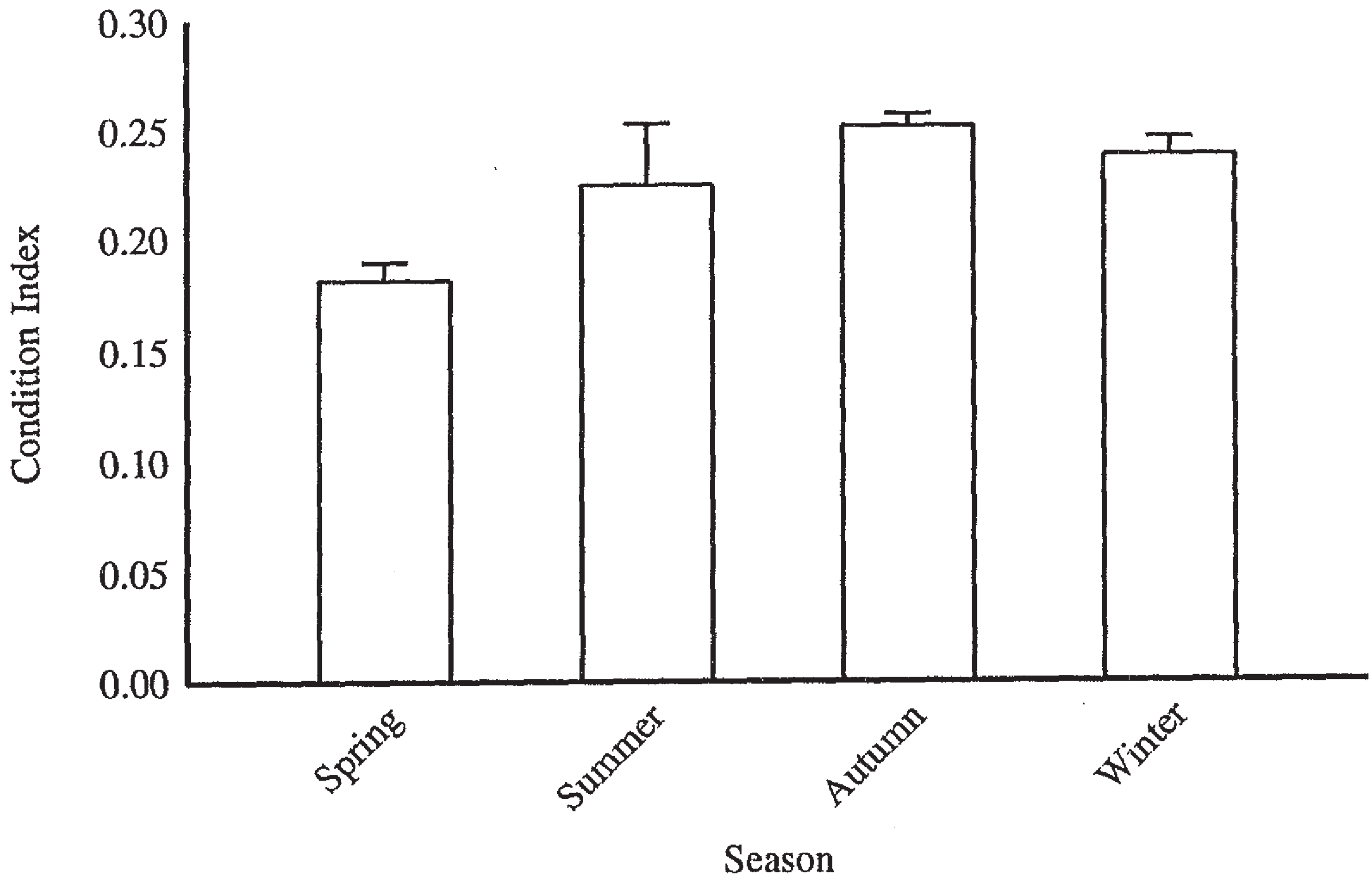

0.30
0.25
0.20
0.15
0.10
0.05
0.00
Condition Index
Spring
Summer
Autumn
Winter
Season

Figure 9. Seasonal condition by age group of white-tailed deer on Saratoga National Historical Park, Stillwater, NY, 1985-87. Error bars represent 1 standard error.

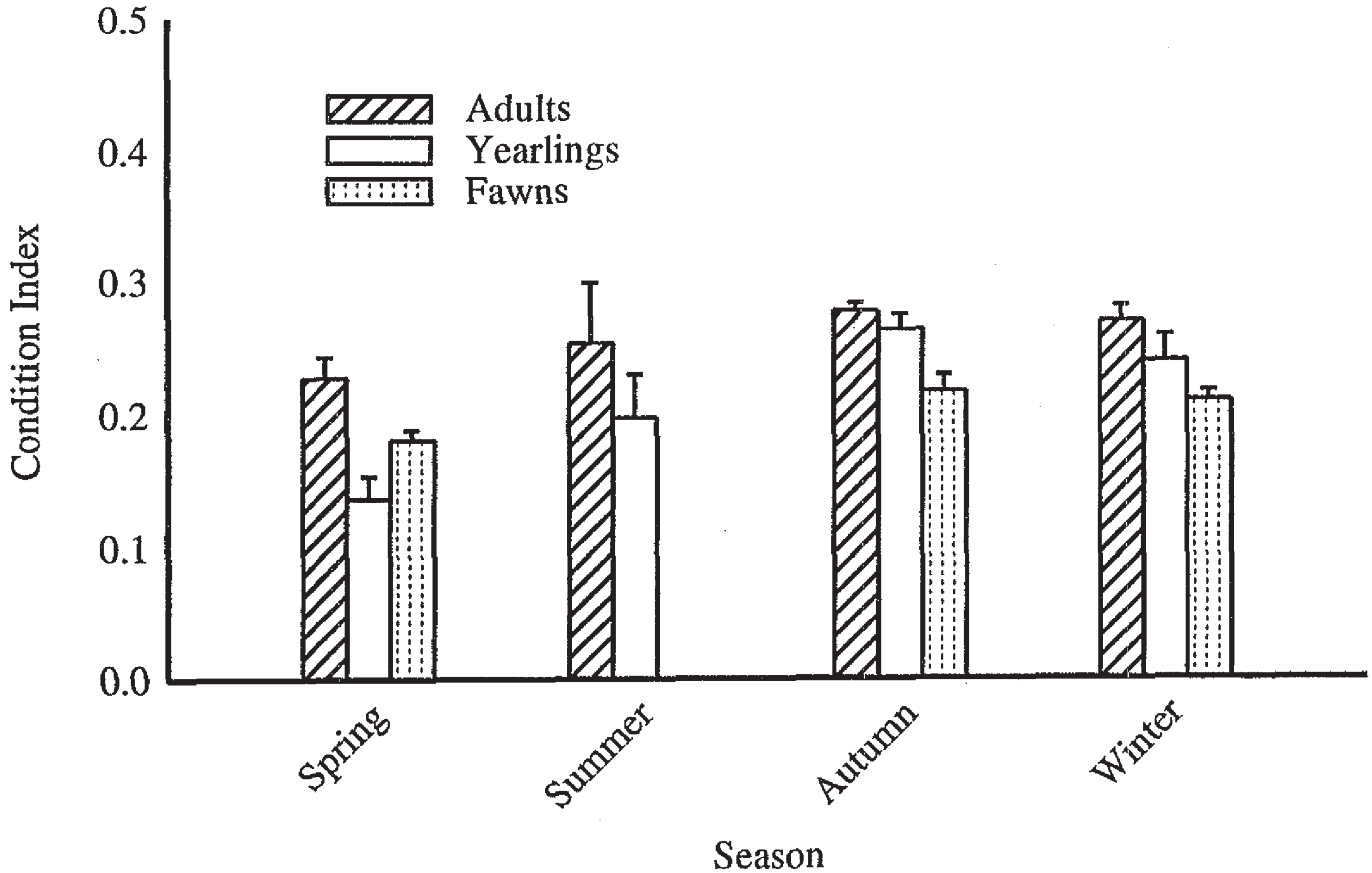
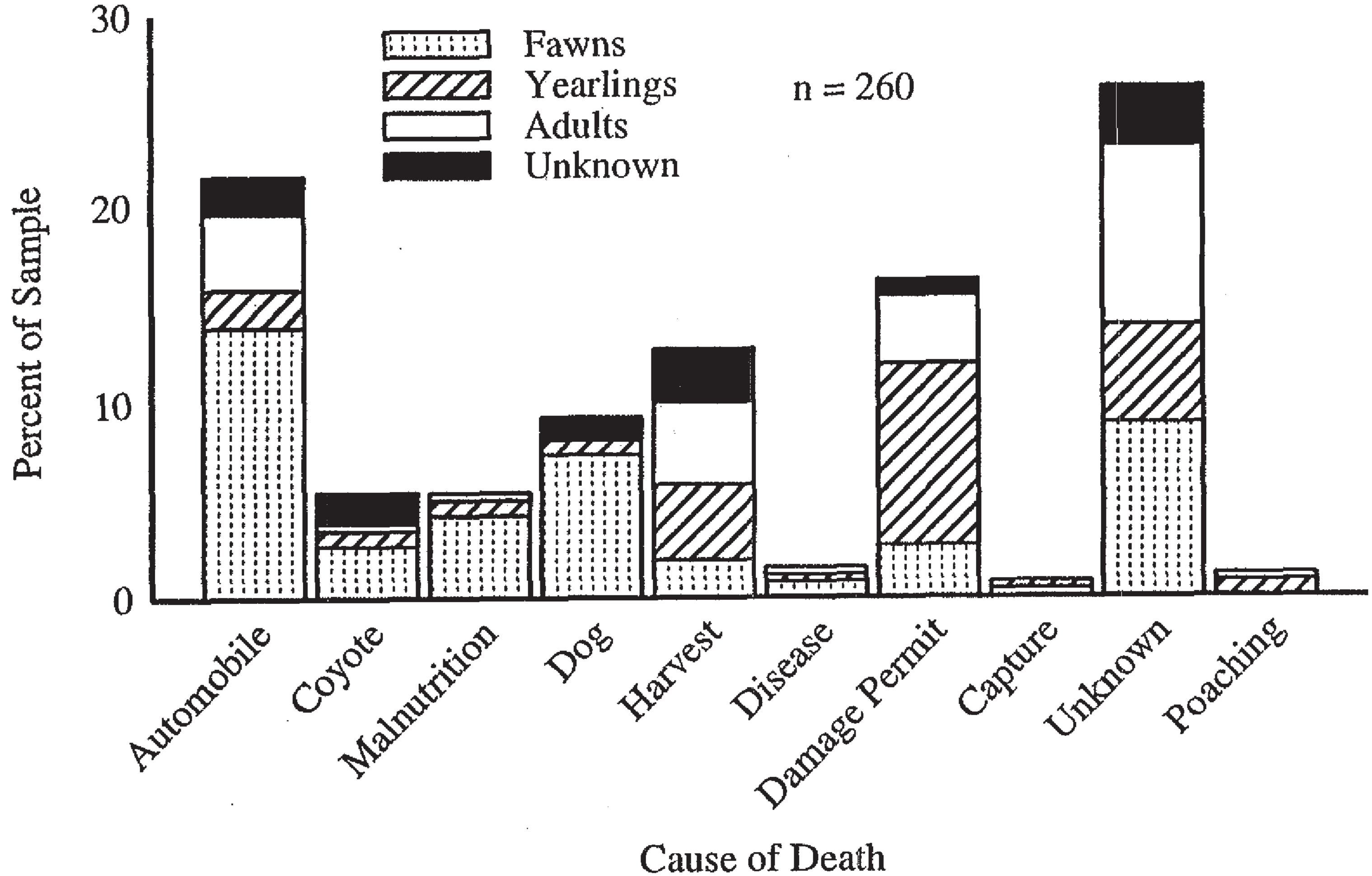

0.5
0.4
0.3
0.2
0.1
0.0
Condition Index
Adults
Yearlings
Fawns
Spring
Summer
Autumn
Winter
Season

Figure 10. Frequency of mortality agents by age group from a sample of white-tailed deer on Saratoga National Historical Park, Stillwater, NY, 1985-87.



30
20
10
0
Percent of Sample
Fawns
Yearlings
Adults
Unknown
n = 260
Automobile
Coyote
Malnutrition
Dog
Harvest
Disease
Damage Permit
Capture
Unknown
Poaching
Cause of Death

Figure 11. Frequency of mortality agents by sex from a sample of white-tailed deer on Saratoga National Historical Park, Stillwater, NY, 1985-87.

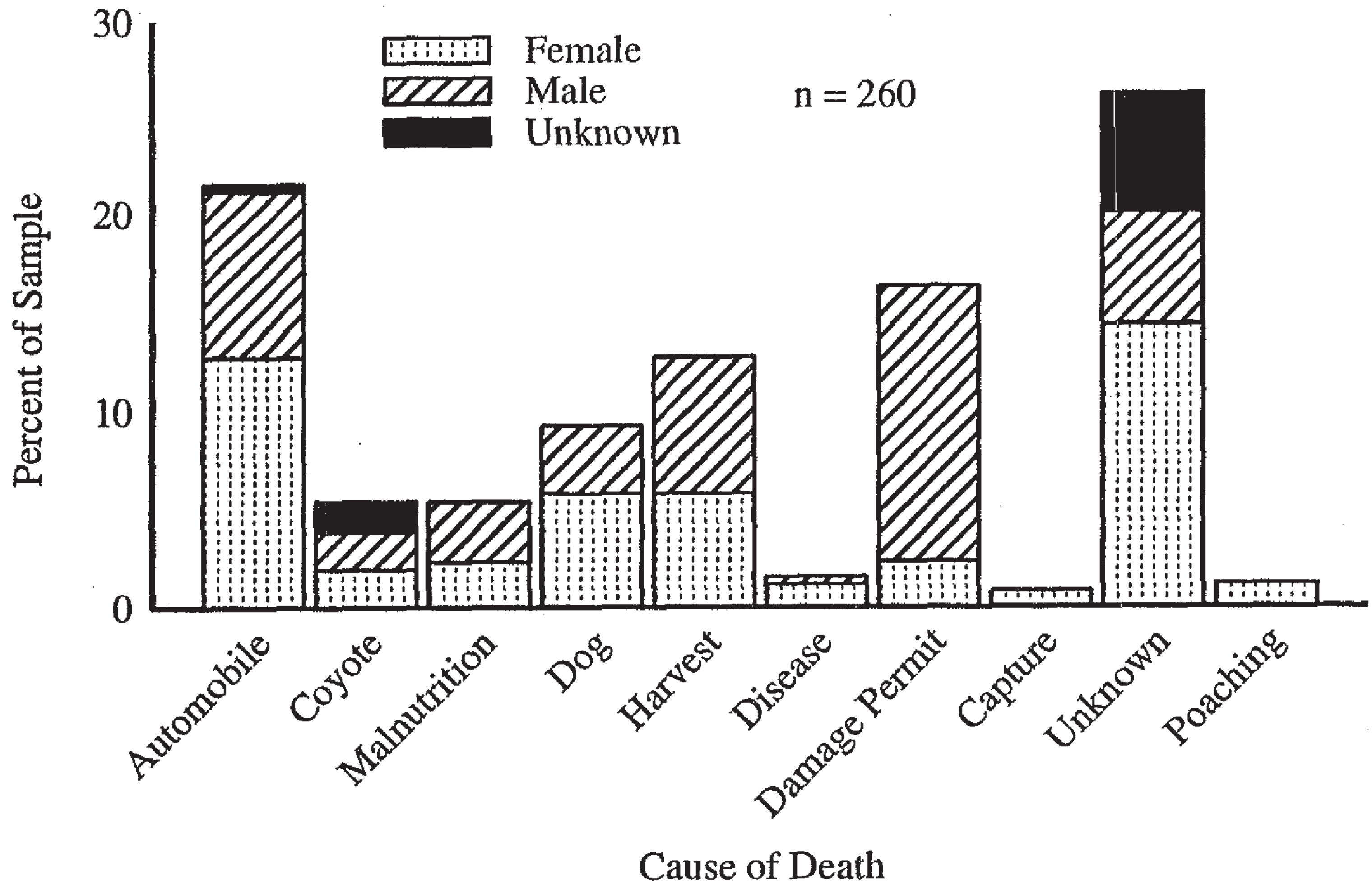
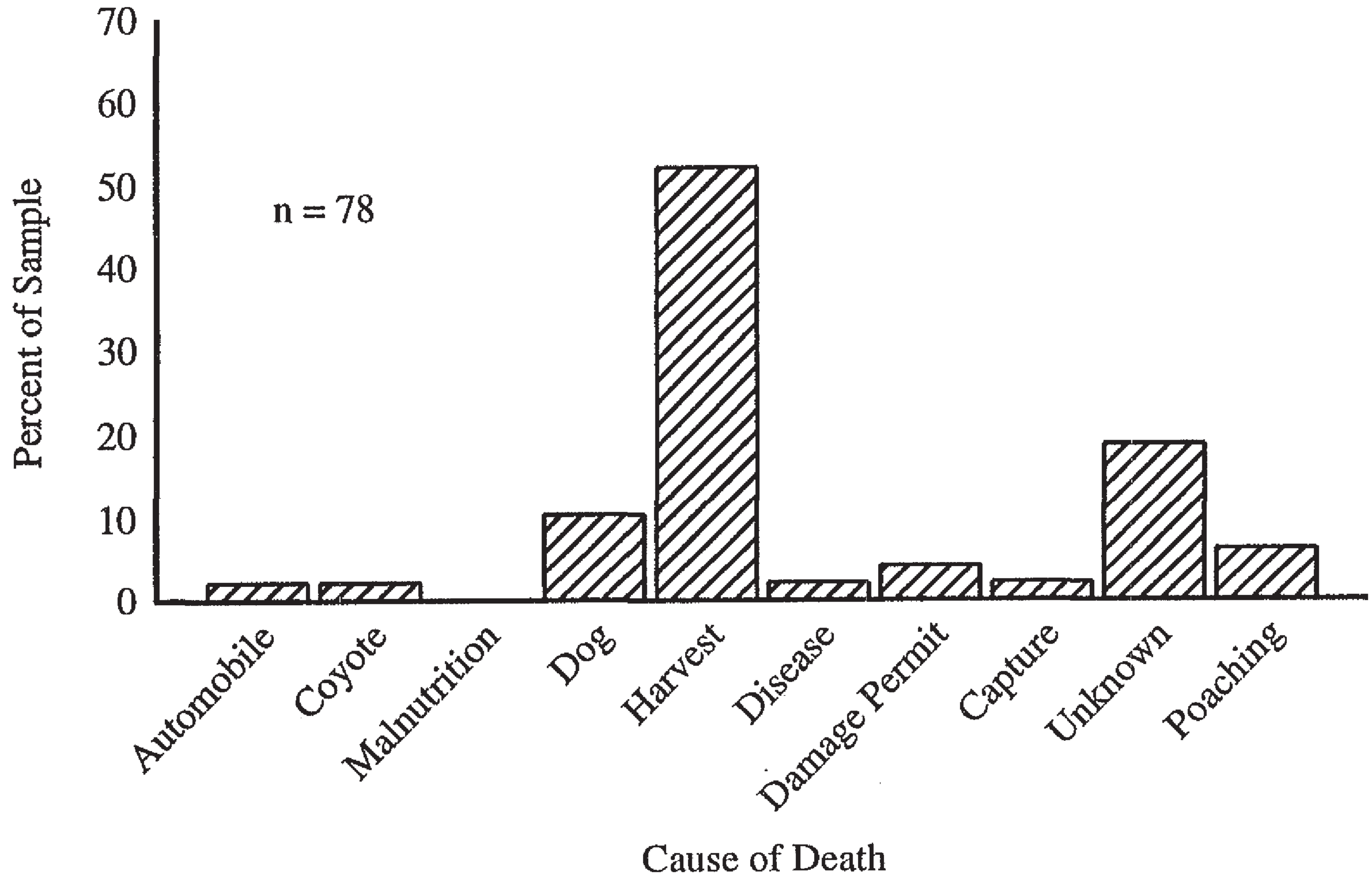
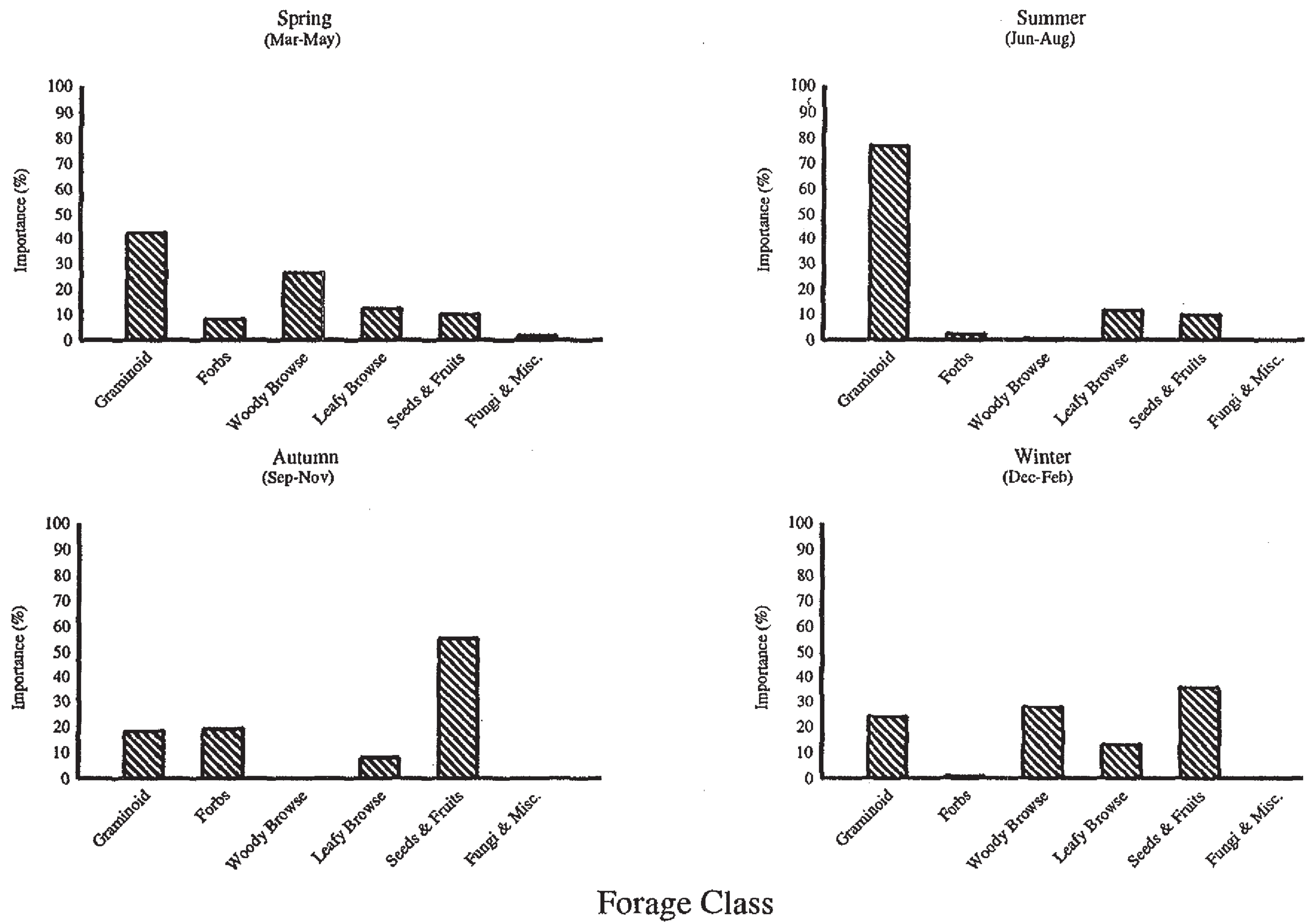

30
20
10
0
Percent of Sample
Female
Male
Unknown
n = 260
Automobile
Coyote
Malnutrition
Dog
Harvest
Disease
Damage Permit
Capture
Unknown
Poaching
Cause of Death

Figure 12. Cause-specific agents of mortality from a sample of radio-collared white-tailed deer on Saratoga National Historical Park, Stillwater, NY, 1985-87.



70
60
50
40
30
20
10
0
Percent of Sample
n = 78
Automobile
Coyote
Malnutrition
Dog
Harvest
Disease
Damage Permit
Capture
Unknown
Poaching
Cause of Death

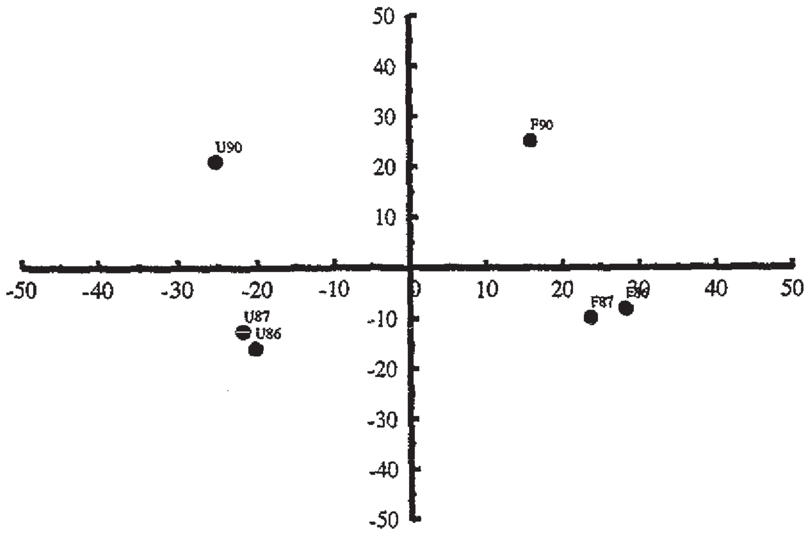
Figure 13. Seasonal food habits of white-tailed deer on Saratoga National Historical Park, Stillwater, NY, 1985-87.



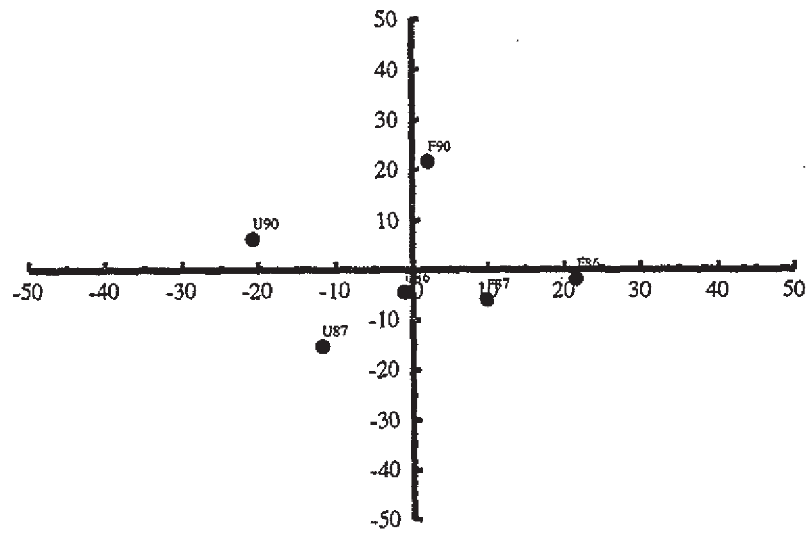
Spring
(Mar-May)
Summer
(Jun-Aug)
Autumn
(Sep-Nov)
Winter
(Dec-Feb)
Importance (%)
0
10
20
30
40
50
60
70
80
90
100
Graminoid
Forbs
Woody Browse
Leafy Browse
Seeds & Fruits
Fungi & Misc.
Forage Class

Figure 14. Ordinations of time-specific changes of leading dominants within treatment plots at Exclosure 1 on Saratoga National Historical Park, Stillwater, NY, 1986-90. F = fenced, U = unfenced.

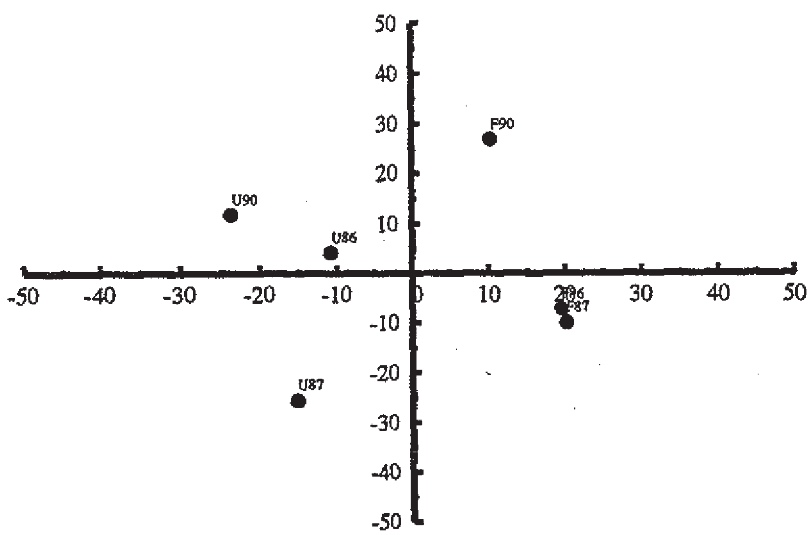
Fall Burn Plots



Spring Burn Plots



Control Plots



Mowed Plots

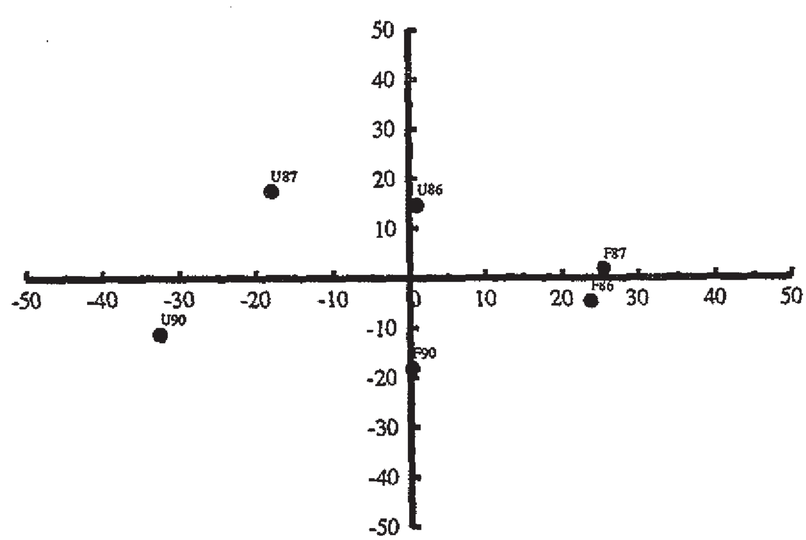
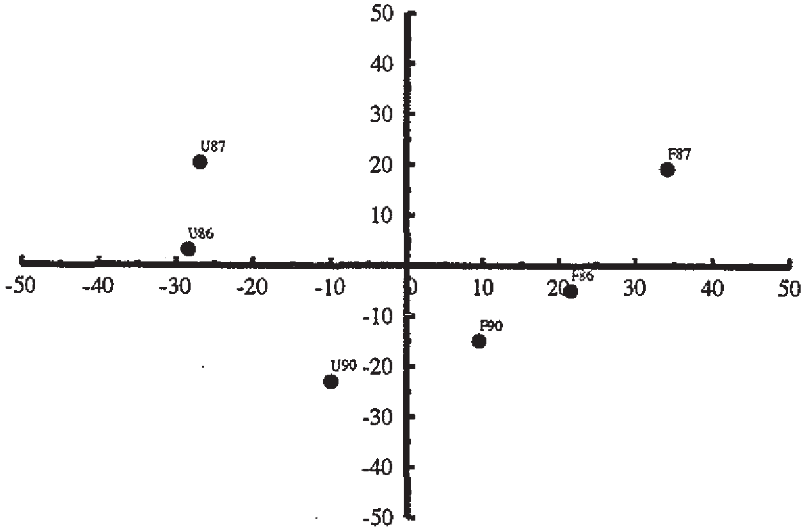
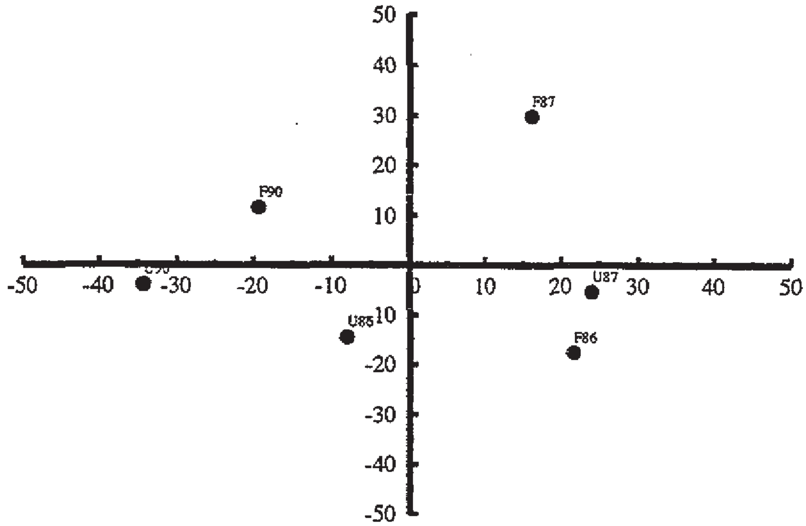


Figure 15. Ordinations of time-specific changes of leading dominants within treatment plots at Exclosure 2 on Saratoga National Historical Park, Stillwater, NY, 1986-90. F = fenced, U = unfenced.

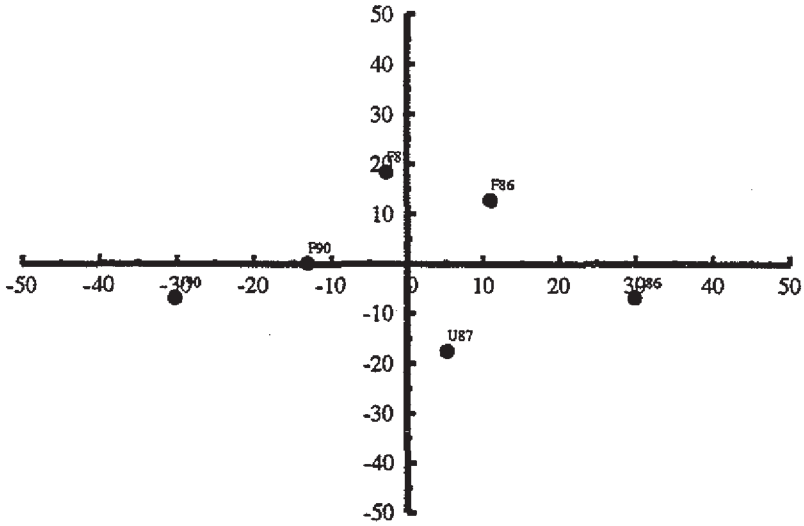
Fall Burn Plots



Spring Burn Plots



Control Plots



Mowed Plots

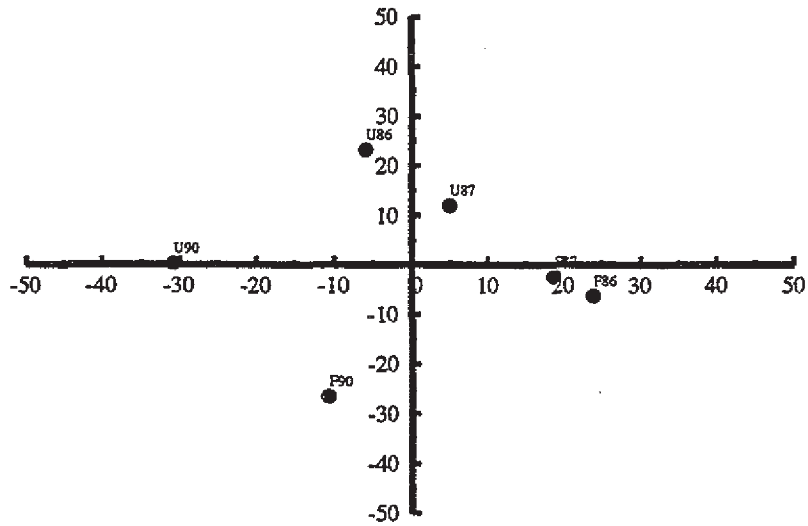
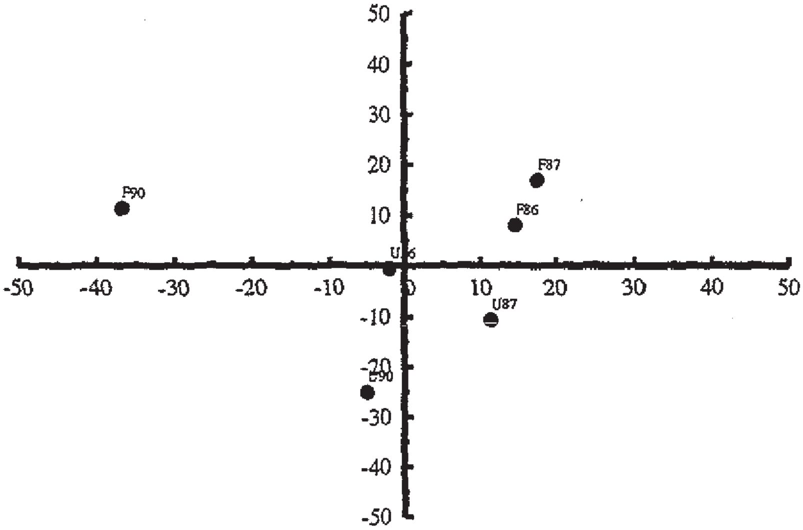
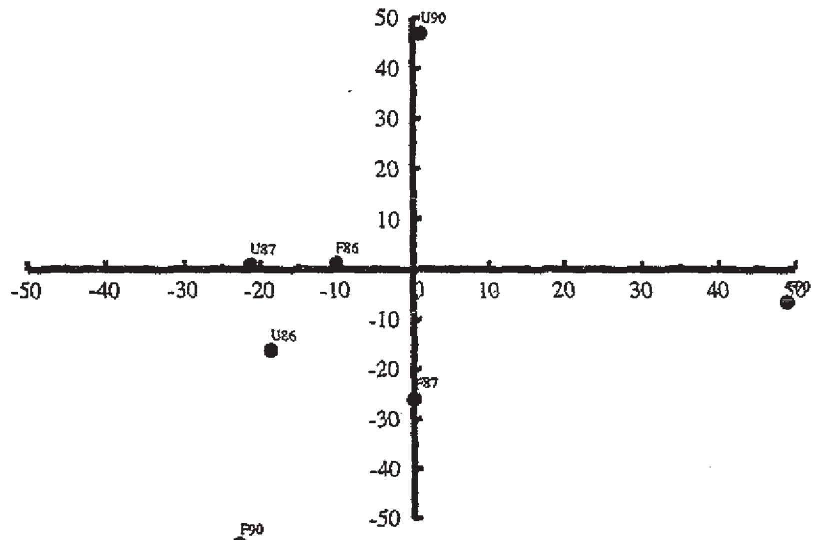


Figure 16. Ordinations of time-specific changes of leading dominants within treatment plots at Exclosure 3 on Saratoga National Historical Park, Stillwater, NY, 1986-90. F = fenced, U = unfenced.

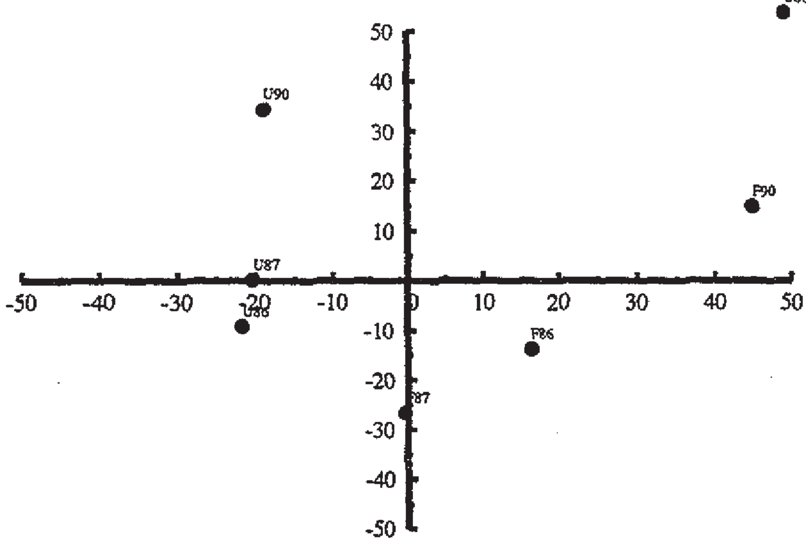
Fall Burn Plots



Spring Burn Plots



Control Plots



Mowed Plots

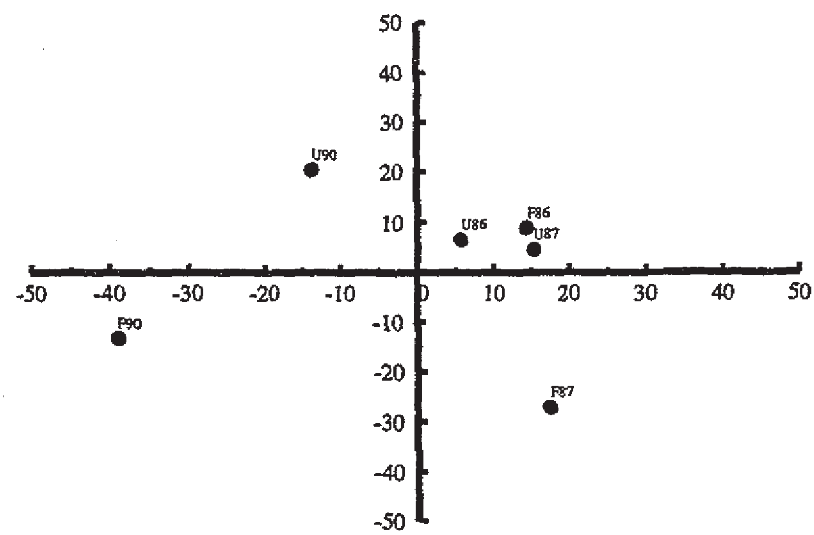
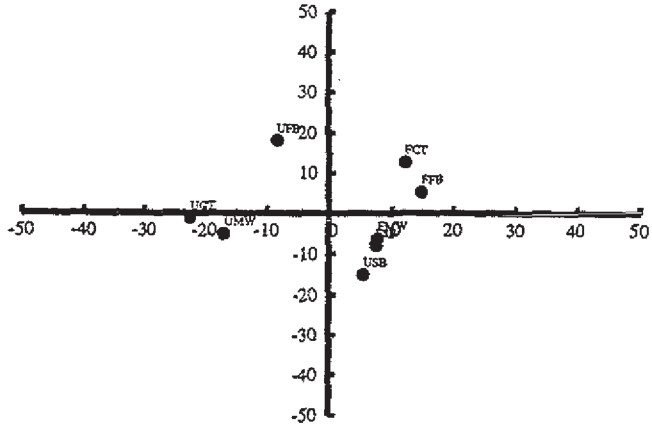
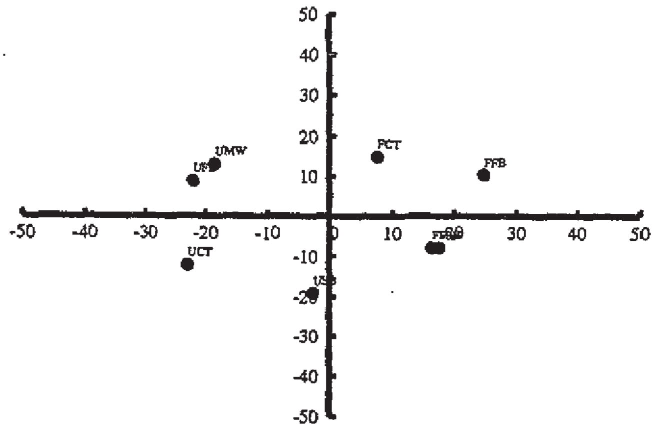


Figure 17. Ordinations of treatment-specific changes of leading dominants over time at Exclosure 1 on Saratoga National Historical Park, Stillwater, NY, 1986-90. F = fenced, U = unfenced. Treatments are control (CT), fall burn (FB), mow (MW), and spring burn (SB).

1990



1987



1986

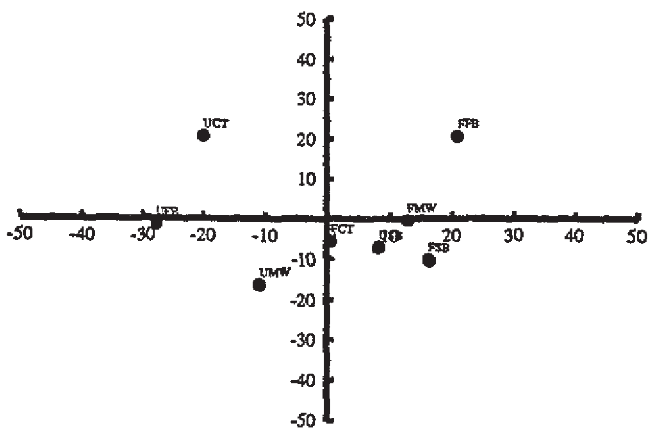
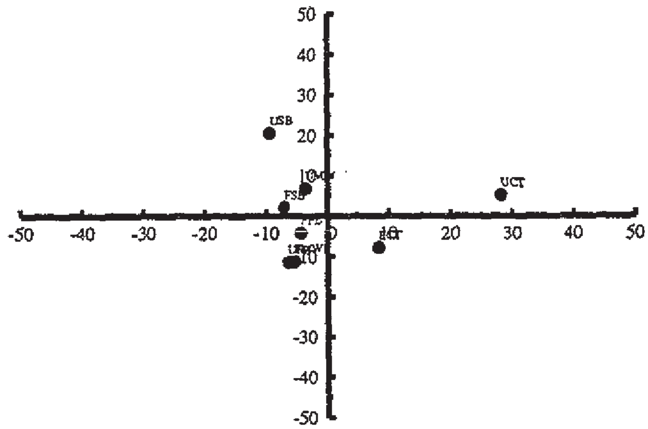
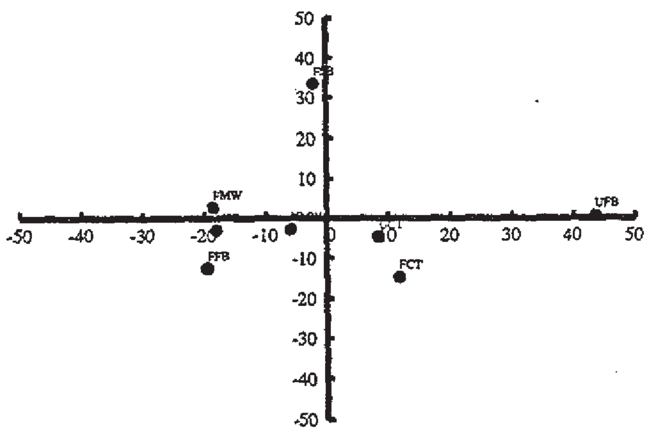


Figure 18. Ordinations of treatment-specific changes of leading dominants over time at Exclosure 2 on Saratoga National Historical Park, Stillwater, NY, 1986-90. F = fenced, U = unfenced. Treatments are control (CT), fall burn (FB), mow (MW), and spring burn (SB).

1990



1987



1986

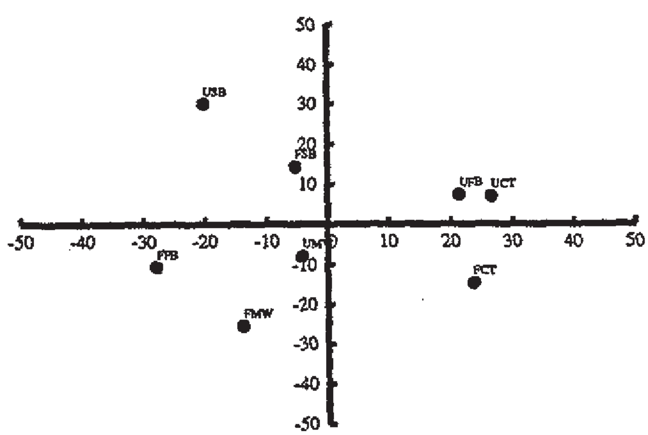
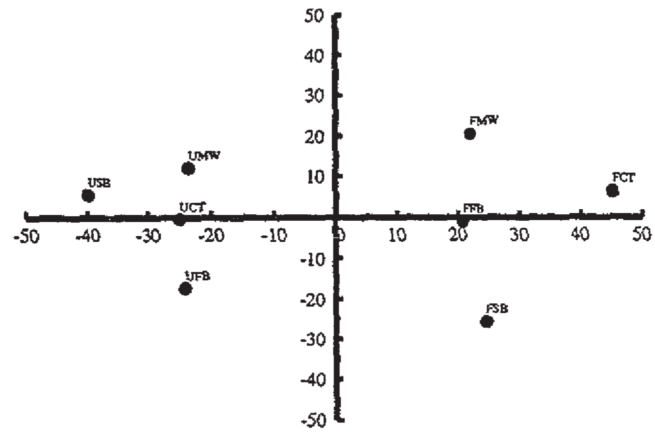
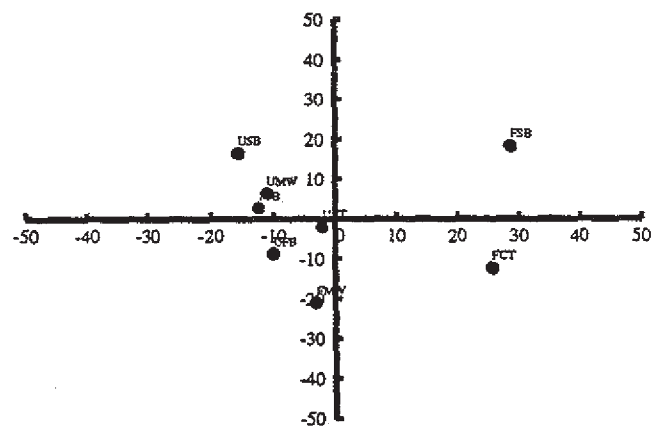


Figure 19. Ordinations of treatment-specific changes of leading dominants over time at Exclosure 3 on Saratoga National Historical Park, Stillwater, NY, 1986-90. F = fenced, U = unfenced. Treatments are control (CT), fall burn (FB), mow (MW), and spring burn (SB).

1990



1987



1986

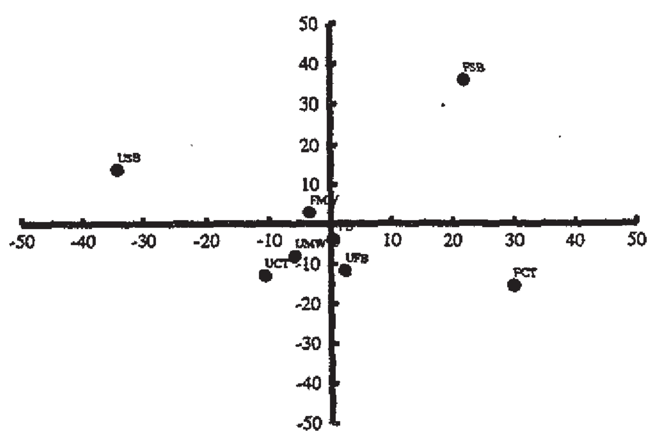
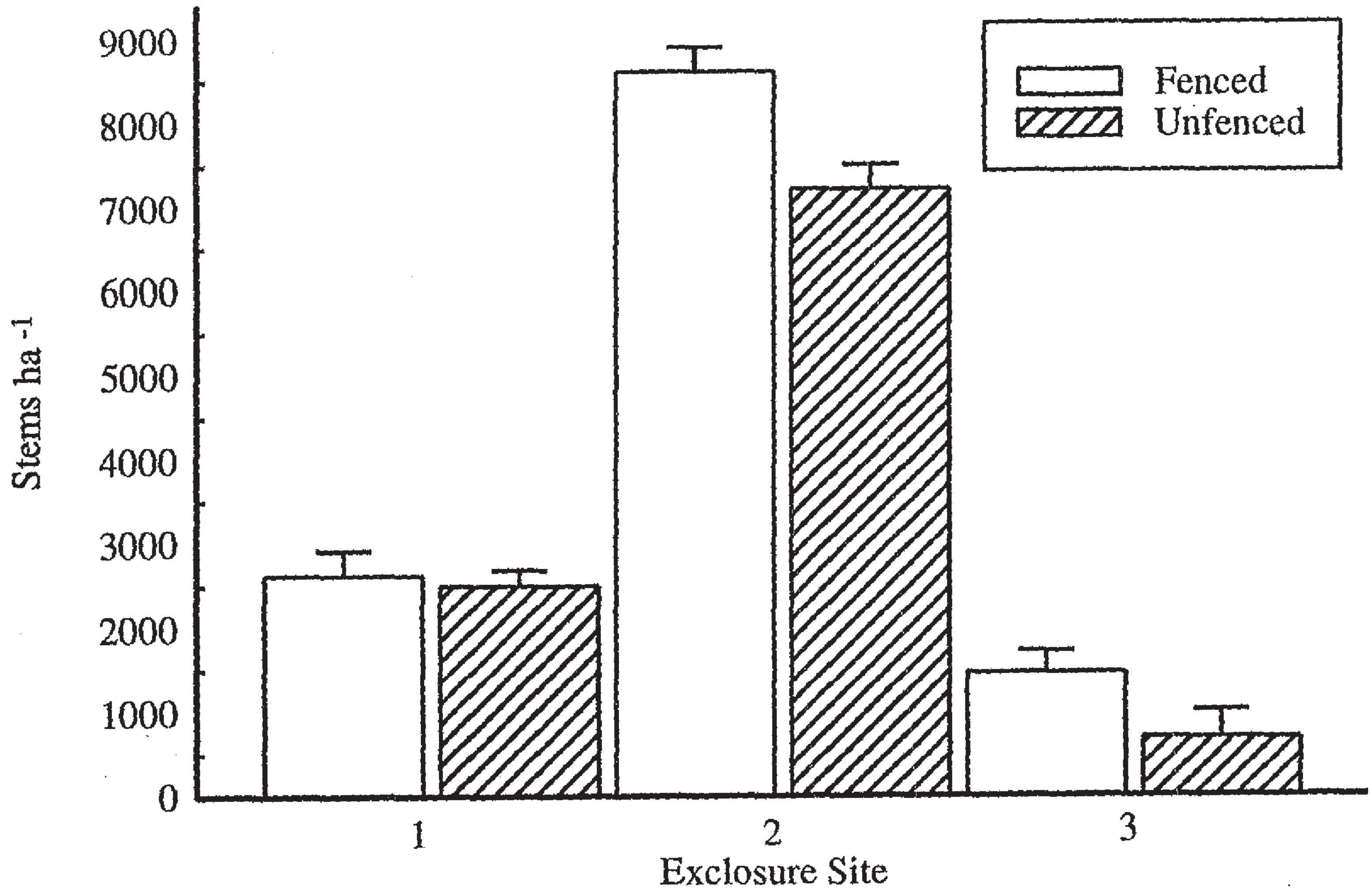
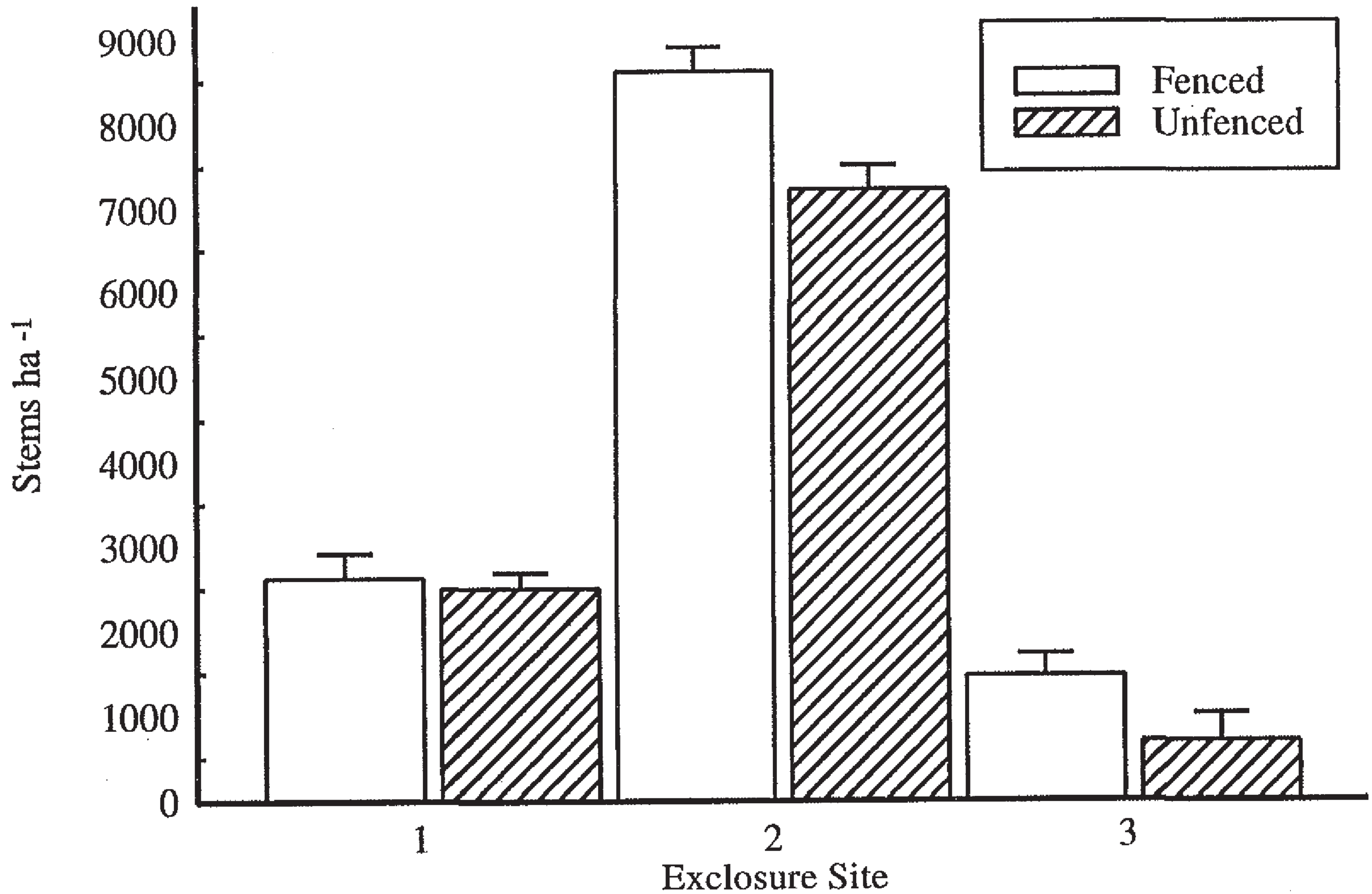


Figure 20. Seedling density in fenced and unfenced areas of 3 old field exclosure sites at Saratoga National Historical Park, Stillwater, NY, 1990. Error bars represent 1 standard error.



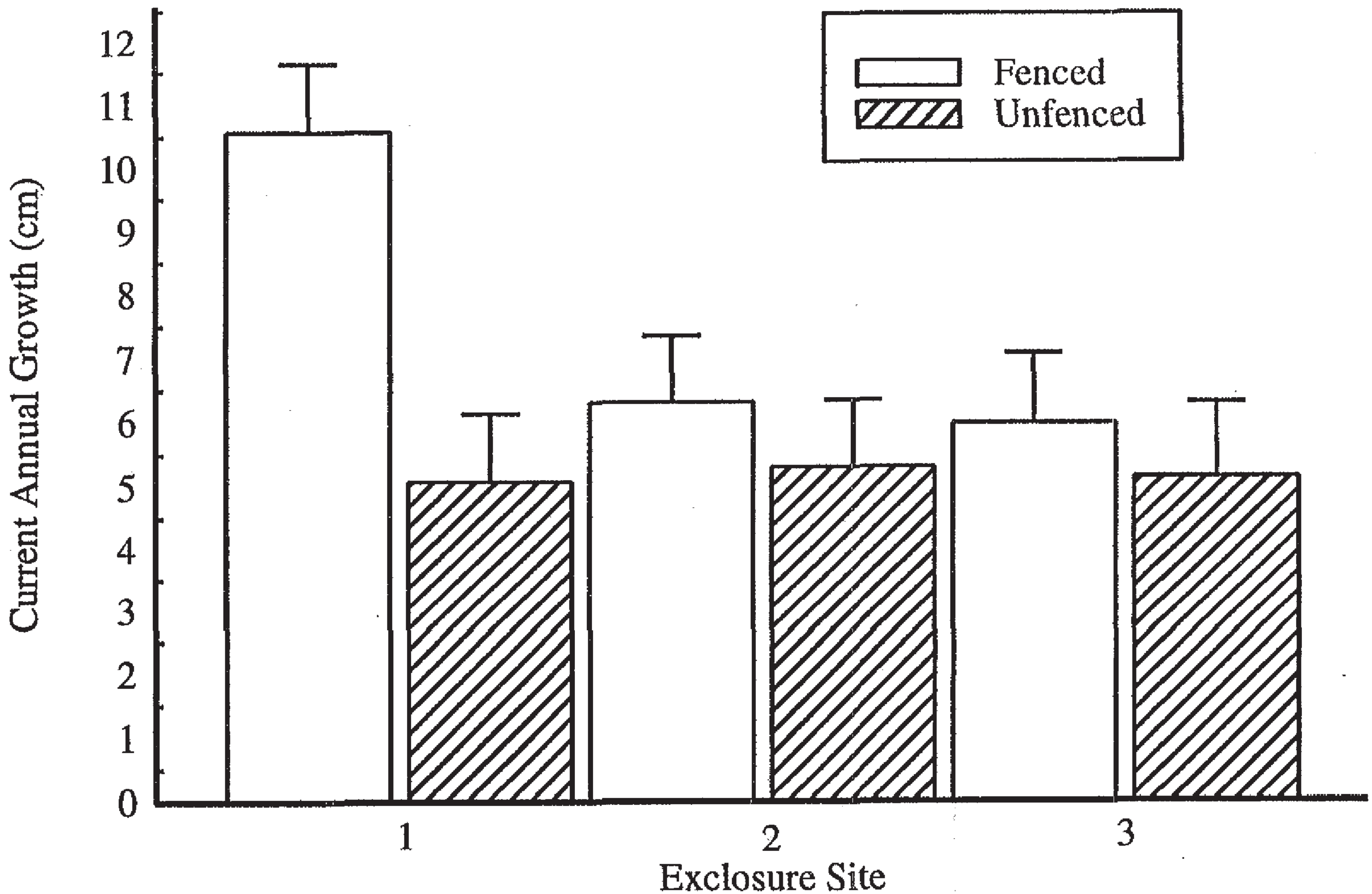
Fenced
Unfenced
Stems ha -1
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
1
2
3
Exclosure Site



9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Stems ha -1
Fenced
Unfenced
1
2
3
Exclosure Site

Figure 20. Seedling density in fenced and unfenced areas of 3 old field exclosure sites at Saratoga National Historical Park, Stillwater, NY, 1990. Error bars represent 1 standard error.

Figure 21. Comparison of current annual growth among established seedlings in fenced and unfenced areas of 3 old field exclosure sites at Saratoga National Historical Park, Stillwater, NY, 1990. Error bars represent 1 standard error.



Fenced
Unfenced
Current Annual Growth (cm)
0
1
2
3
4
5
6
7
8
9
10
11
12
1
2
3
Exclosure Site

Figure 22. Distribution of seedling heights in fenced and unfenced areas at Exclosure 1 on Saratoga National Historical Park, Stillwater, NY, 1990.

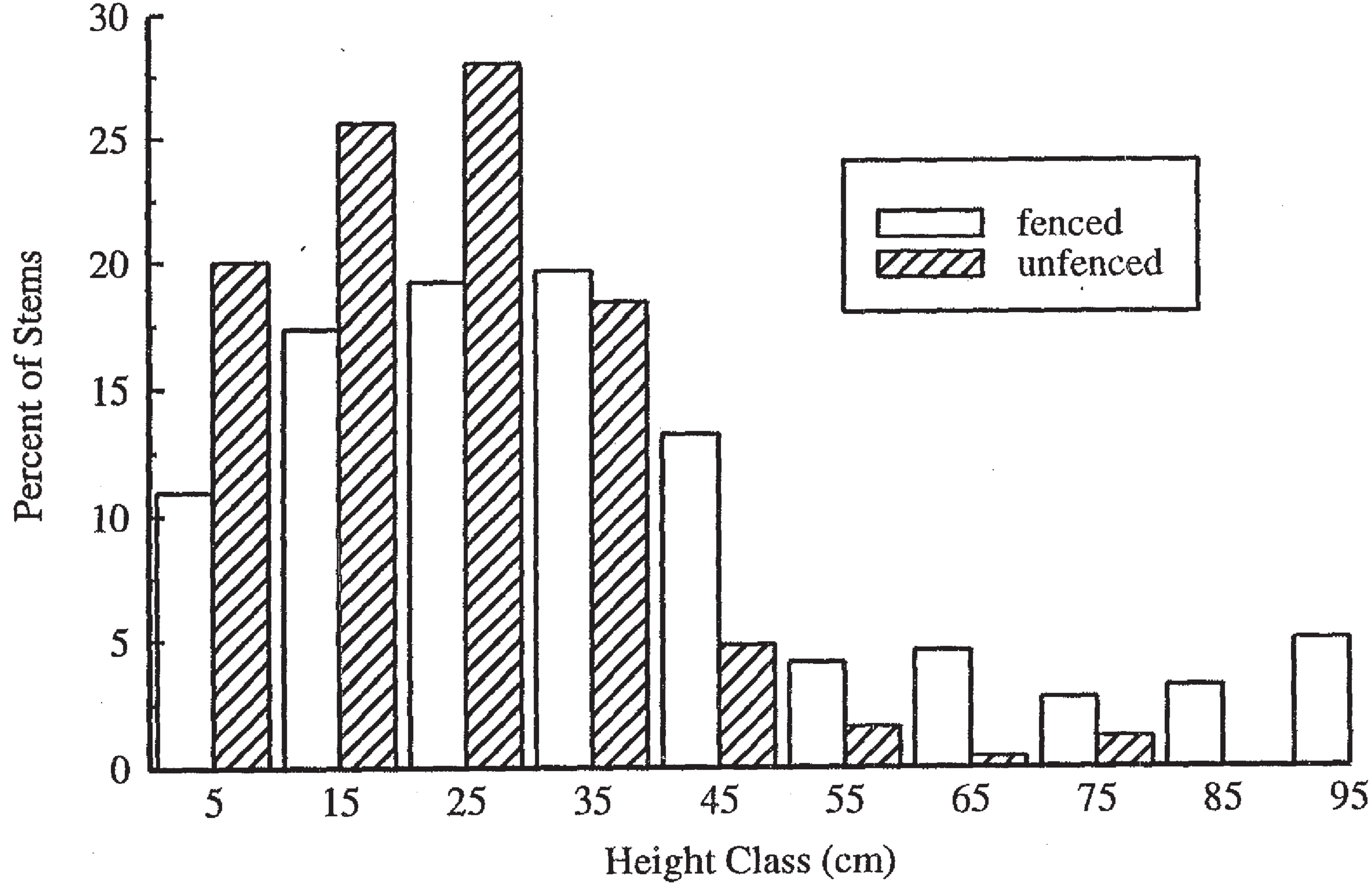
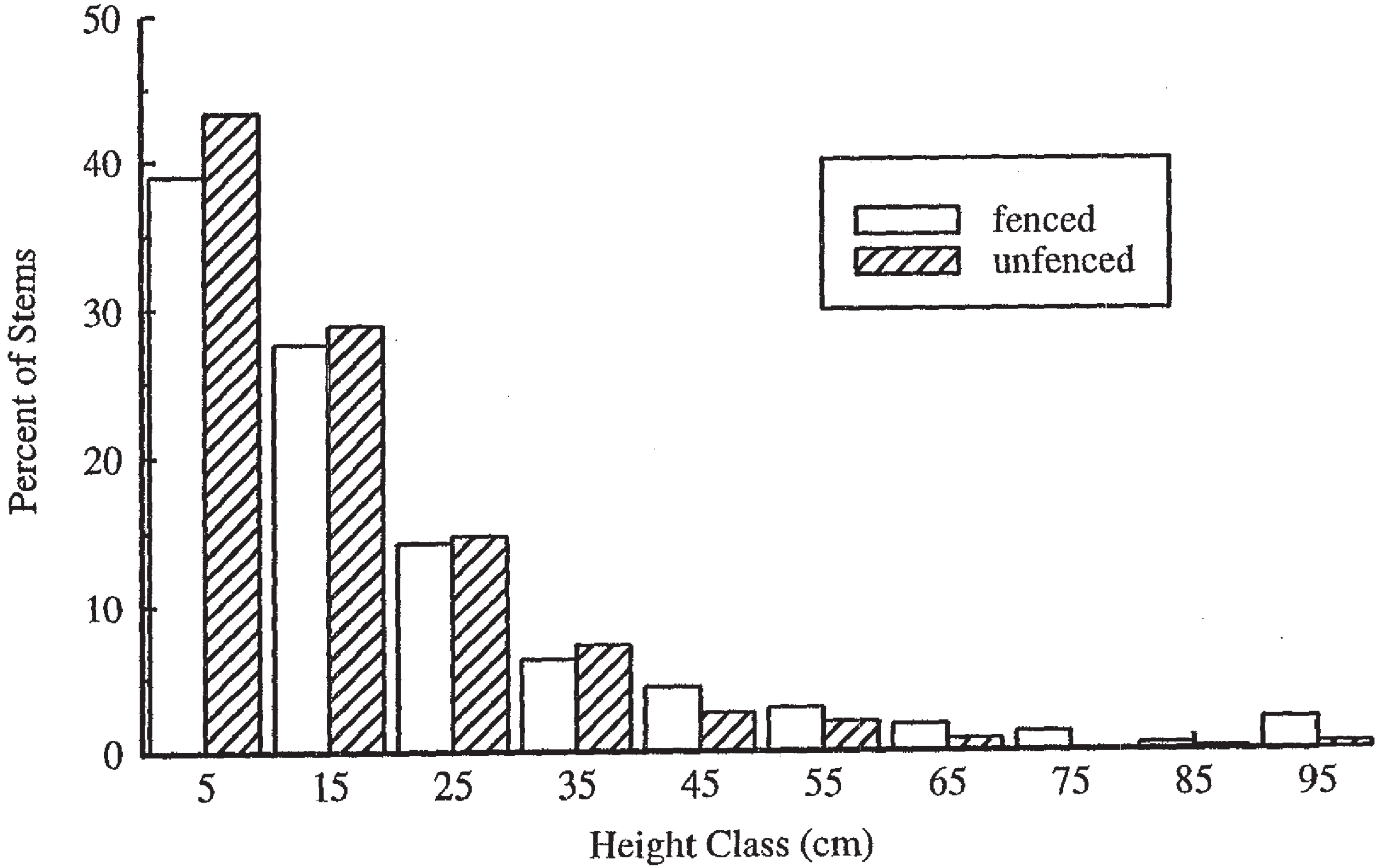
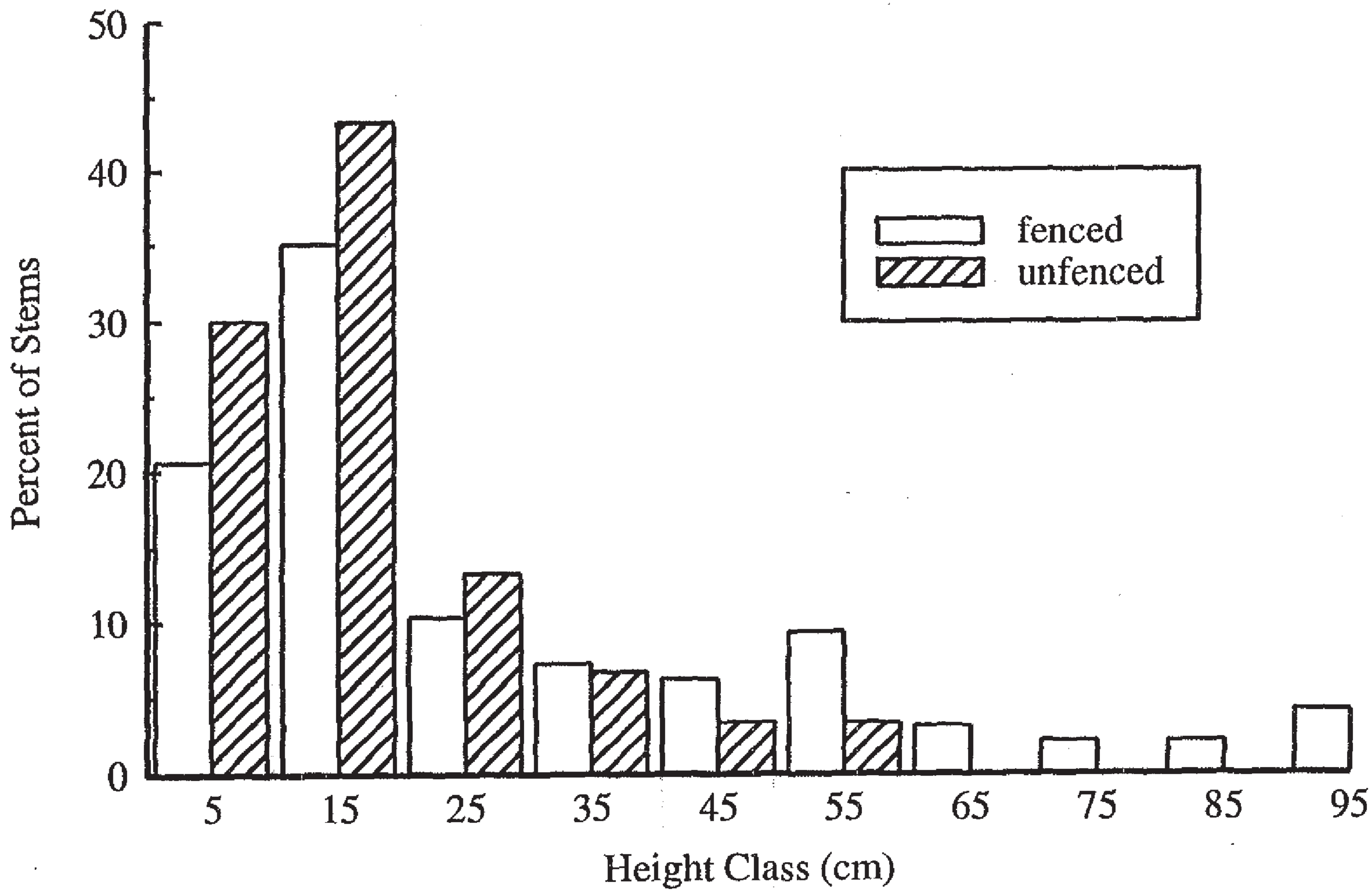

30
25
20
15
10
5
0
Percent of Stems
fenced
unfenced
5
15
25
35
45
55
65
75
85
95
Height Class (cm)

Figure 23. Distribution of seedling heights in fenced and unfenced areas at Exclosure 2 on Saratoga National Historical Park, Stillwater, NY, 1990.



50
40
30
20
10
0
Percent of Stems
fenced
unfenced
5
15
25
35
45
55
65
75
85
95
Height Class (cm)

Figure 24. Distribution of seedling heights in fenced and unfenced areas at Exclosure 3 on Saratoga National Historical Park, Stillwater, NY, 1990.


Percent of Stems
50
40
30
20
10
0
fenced
unfenced
5
15
25
35
45
55
65
75
85
95
Height Class (cm)

Appendix I. Common and scientific names of species used in the Final Report on Interactions of Deer and Vegetation at Saratoga National Historical Park.

American beech	Fagus grandifolia
American elm	Ulmus americana
Apple	Pyrus malus
Arrow-wood	Viburnum recognitum
Big-toothed aspen	Populus grandidentata
Black willow	Salix nigra
Common buckthorn	Rhamnus cathartica
Cottonwood	Populus deltoides
Coyote	Canis latrans
Dog	Canis familiaris
Eastern hop-hornbeam	Ostrya virginiana
Eastern hemlock	Tsuga canadensis
Ferns	Osmunda spp.
Flowering maple	Viburnum acerifolium
Gray birch	Betula populifolia
Gray dogwood	Cornus racemosa
Hawthorn	Crataegus spp.
Hornbeam	Carpinus caroliniana
Huckleberry	Berberis spp.
Kentucky bluegrass	Poa pratensis
Nannyberry	Viburnum lentago
Northern prickly ash	Zanthoxylum americanum
Northern red oak	Quercus rubra
Quaking aspen	Populus tremuloides
Red maple	Acer rubrum
Red-osier dogwood	Cornus stolonifera
Slippery elm	Ulmus rubra
Speckled alder	Alnus rugosa
Steeplebush	Spiraea latifolia
Sugar maple	Acer saccharum
Tartarian honeysuckle	Lonicera tatarica
White oak	Quercus alba
White ash	Fraxinus americana
White pine	Pinus strobus
White-tailed deer	Odocoileus virginianus
Wild black cherry	Prunus serotina
Witch-hazel	Hamamelis virginiana

As the nations's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural and cultural resources. This includes fostering wise use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for enjoyment of life through outdoor recreation. The department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people. The department also promotes the goals of the Take Pride in America campaign by encouraging stewardship and citizen responsibility of the public lands and promoting citizen participation in their care. The department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

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