Assateague Island National Seashore

Assessment of the Effects of Feral Horses, Sika Deer and White-Tailed Deer on Assateague Island's Forest and Shrub Habitats

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Abstract

Native white-tailed deer (*Odocoileus virginianus*) and non-native sika deer (*Cervus nippon*) inhabit Assateague Island National Seashore (ASIS) along with feral horses (*Equus caballus*). During the fall of 2002 four forest and four shrub study sites were established in order to monitor the impacts of deer and horse herbivory within these habitats. Each study site included three treatments: a horse and deer exclosure (Total), a horse only exclosure (Partial) and a Control treatment where both deer and horses were allowed to forage. Between 2003 and 2005 pin-contact, cover-board and deer browse data were collected at each study site. Additionally, both deer populations were estimated each winter (2003-2006), post hunting season, using distance-sampling. During this research, existing levels of ungulate herbivory were shown to significantly reduce species richness, evenness and diversity in maritime forest habitats as well as to alter the vegetative community composition in both habitats. In addition, many plant taxa responded significantly to project treatments through changes in their abundance or mean height. These responses were frequently directly attributable to either deer or horse herbivory, or the combined affect of both groups. This information will be used in conjunction with that provided by other ongoing research, investigating deer movements and habitat utilization, to develop monitoring protocols designed to reflect the status and trends of ASIS deer populations, as well as to quantify the vegetative effects of existing levels of herbivory. Ultimately, these vegetation monitoring protocols will form part of an adaptive management program that will help ASIS make informed decisions regarding the management of Assateague Island's terrestrial flora and fauna communities.

Introduction

Assateague Island is located along the Atlantic coast of Maryland and Virginia. The island is roughly 57 km long and ranges between 0.3 and 2.8 km in width. Three separate governmental agencies manage certain sections of the island. Assateague Island National Seashore (ASIS) is managed by the National Park Service (NPS) and encompasses 30 km of Maryland's 35 km portion of the island, with the remaining 5 km being managed separately by the Maryland Department of Natural Resources as Assateague State Park. The Virginia portion of Assateague Island is managed by the US Fish and Wildlife Service as part of the Chincoteague National Wildlife Refuge (CNWR).

Both native white-tailed deer (*Odocoileus virginianus*) and non-native sika deer (*Cervus nippon*) currently inhabit the island. ASIS also has a large feral horse (*Equus caballus*) population. The ASIS horse population has free range over the Maryland end of Assateague Island, including both those areas occupied by the State Park and National

Seashore. This population has been closely monitored by park staff since the 1980's and has been subjected to a contraceptive program that has effectively halted population growth since 1994 (Kirkpatrick 1995). Horse movement is restricted between ASIS and CNWR by a fence at the Maryland-Virginia state line. This state line fence does not however, restrict deer movement between ASIS and CNWR. The NPS has identified the need to better understand the ecological role of horses and deer on Assateague Island in order to develop appropriate, scientifically based, long-term management strategies.

Today, throughout the eastern United States, white-tailed deer populations are reaching historic highs, largely as a result of their successful adaptation to human induced landscape alterations and species management, which has encouraged population expansion. The problems that these high deer densities present to natural resource managers began to be researched and understood during the 1980's and 1990's (Underwood and Porter 1997). Waller and Alverson (1997) conducted a review of deer research and concluded that current methods for estimating and managing deer populations used by most state agencies are outdated and insufficient for making informed decisions. Other studies have closely examined the ecological role of deer in other areas (Tilghman 1989; Miller, et al. 1992; Strole and Anderson 1992; Waller and Alverson 1997; ; Healy 1997; McShea and Rappole 2000; Liang and Seagle 2002). These studies, among others, demonstrated that high and even moderate deer densities can influence flora and fauna species diversity as well as ecosystem structure and function.

Tilghman (1989) found that browsing by white-tailed deer was the major cause of regeneration failure in Allegheny hardwood forests. Stole and Anderson (1992) found that selective deer browsing (at high deer density) could effect a change in tree species composition in the forest understory. McShea and Rappole (2000) found that changes in understory vegetation, attributable to deer browse, accounted for most of the variability seen in the abundance and diversity of bird populations, and that populations of deer in protected areas (i.e. National Parks) are capable of causing significant shifts in the composition and abundance of bird communities. Miller, et al. (1992) found that ninety-eight species of threatened or endangered plants were reported disturbed by deer. This finding is especially pertinent to ASIS where seabeach amaranth (*Amaranthus pumilus*), a species federally listed as threatened, is foraged upon by both deer and horses.

Waller and Alverson (1997), McShea and Rappole (1997), and Healy (1997) among others recommend conducting research into the ecological impact of deer populations and using browse sensitive plant species as indicators of current deer population status and trends. Prior to this study, the combined effects of deer and horse herbivory had never been examined on Assateague Island, nor had there been an attempt to isolate the effects of deer herbivory on Assateague's vegetative communities.

During the 1980's several attempts were made to estimate the sika and white-tailed deer populations on ASIS (Keiper and Tzilkowski 1983, Tzilkowski and Brown 1984; Tzilkowski and Brown 1985; Tzilkowski 1986). Given the estimation methods used (fecal counts, change in ratio, etc). none of which included a survey of all habitats utilized by both deer species and the stochastic nature of habitat selection expressed by deer, these efforts met with only limited success.

At the onset of this project, the unknown size of the population of either deer species motivated ASIS resource managers to undertake a project using distance-sampling and Distance® software (Buckland, et al 2001). Distance-sampling is a robust and comparatively cost effective method of estimating wildlife populations that is used by the NPS' Inventory and Monitoring Division, among other organizations.

The Distance® generated estimates coincided with the ongoing investigation into ASIS's vegetative community response to deer herbivory. As a result the observed vegetation responses can be compared against the estimated intensity of herbivory by both deer species and used to develop and test monitoring protocols designed to quantify deer effects. Ultimately, the intent of this project is to develop long-term vegetation monitoring protocols, as part of an adaptive management program, that will allow ASIS to make informed decisions regarding the management of Assateague Island's terrestrial flora and fauna communities.

Methods

Preliminary Study Site Selection

Initially, a literature review of sika and white-tailed deer behavior, diet, habitat selection and abundance was conducted in addition to a review of literature pertaining to Assateague Island's vegetation. This information was used to aid in identifying potential study sites, each of which included an abundance of plant species known to be utilized by one, or both deer species. A preliminary search of the island revealed eleven potential study sites

In order to maximize similarity between treatment areas at each study site a preliminary round of pin-sampling was conducted from August through October 2002. Please refer to page 6 for a description of pin-sampling. Each treatment area measured 20m x 30m and during the preliminary round of data collection, proposed treatment areas were systematically pin-sampled using 96 evenly distributed pins. These data were used to generate species relative abundance (RA) estimates.

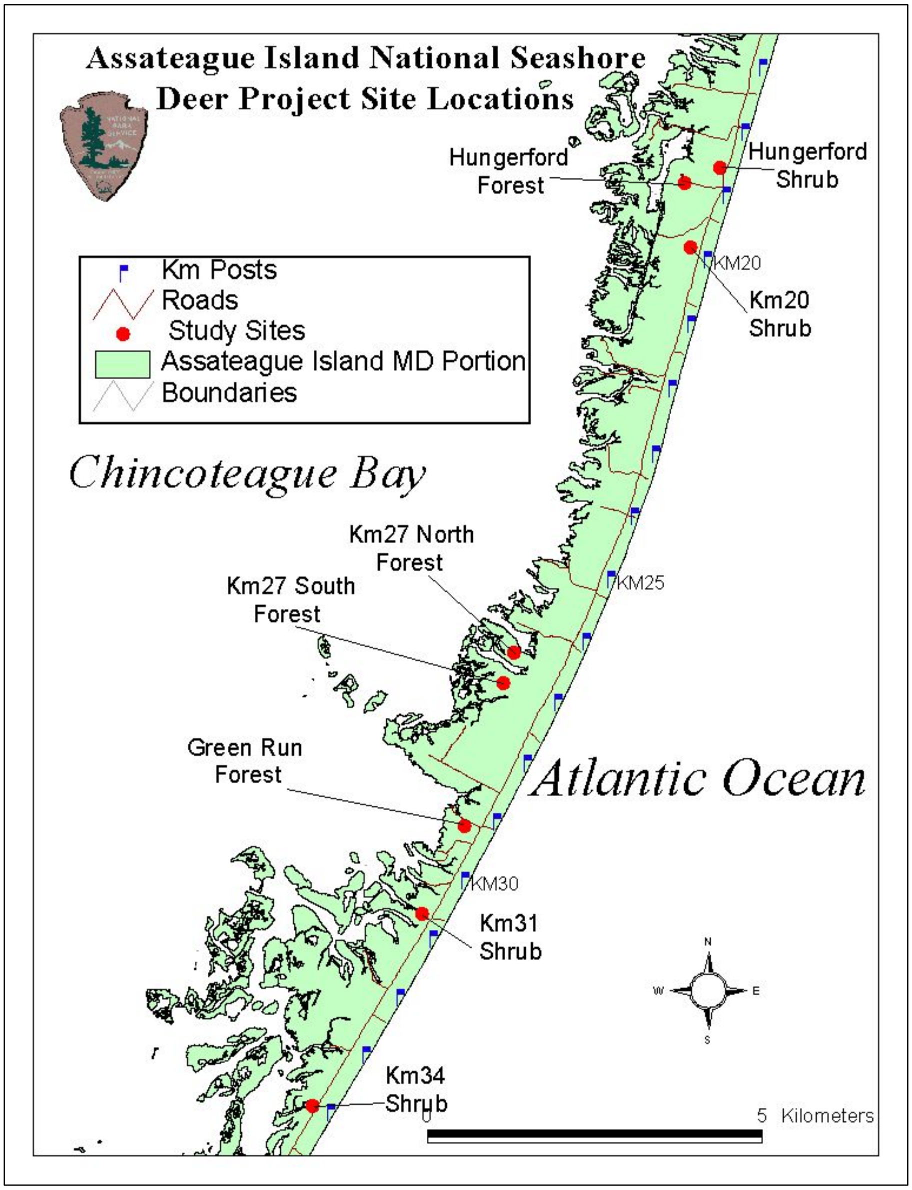
Using the RA estimates generated from the preliminary pin-sampling data, proportional similarity (PS; Culberson 1955, Bray and Curtis 1957, see Figure 1) and heterogeneity (PD = 1 – PS) were calculated between treatment areas at each site. Because RA estimates were used to calculate PS, the constant 2 was used in the equation shown in Figure 1, since the sum of all RA at any given site equals one (i.e. sum of site A + sum of site B = 2). A minimum PS value of 0.6 was required between all three treatment areas at a potential study site for the site to be considered for inclusion in the study. Ultimately, eight study sites were selected, four in closed-canopied maritime forest habitats and four in shrub habitats, see Figure 2.

Figure 1. Bray-Curtis proportional similarity formula

$$PS = \left(2 - \sum_{j=1}^{S} \left| p_{1j} - p_{2j} \right| \right) \Big/ 2$$

Where p_{1j} is the relative (or proportional) abundance of species j at site 1, p_{2j} is the relative abundance of species j at site 2 and S is the total number of species identified.

Figure 2: Map showing study site locations



The four replicate forest study sites were Hungerford Forest, KM 27 North, KM 27 South and Green Run. The abbreviations used in this report for each of the above sites are FHNG, F27N, F27S and FGRN respectively. The four replicate shrub study sites were Hungerford Shrub, KM 20, KM 31 and KM 34. The abbreviations used in this report for each of the above sites are SHNG, SH20, SH31, and SH34 respectively. In both cases the names refer to island landmarks in the vicinity of each site with numbered sites referring to the nearest kilometer post which marks the linear distance on the island south of the Ocean City inlet.

Treatment Descriptions and Exclosure Construction

Three different grazing regimes were established at each study site during the fall of 2002 by randomly assigning different treatments to the areas identified during preliminary sampling. At each study site all treatments areas were in close proximity (<100m distant) to one another. The different treatments, described below, included a Total exclosure treatment, a Partial exclosure treatment and a Control treatment.

Total Exclosure

Total exclosure treatments prevented horse, sika deer and white-tailed deer herbivory within treatment areas and allowed us to monitor the vegetative response to rest from horse and deer herbivory. (note: small vertebrate herbivores were still able to enter Total treatment areas). Each Total exclosure was made of a strong 7'6" plastic mesh material supported by a high tension wire that was wrapped around four reinforced corners. Each corner was constructed with three 4"x4"x12' posts which were first set to form a right-angle to a depth of approximately four feet and then connected near the top by two 2" x 4" x 10' boards. Additionally, the mesh was supported by ten 9' long angle iron bars and staked to the ground with 18" rebar stakes. Finally, a gate was installed at one corner to allow access to the treatment area. See Figure 3.

Partial Exclosure

Partial exclosure treatments were designed to exclude horses while at the same time permit access by both deer species to treatment areas, thereby allowing us to isolate and monitor vegetative responses to deer herbivory only. Each Partial exclosure measured 23m x 33m, with the 20m x 30m treatment area being centrally located inside. This design, which established 1.5m buffer around the perimeter of Partial treatment areas, was intended to prevent horses that grazed through the exclosure fence from impacting the treatment area.

Figure 3. Total exclosure.

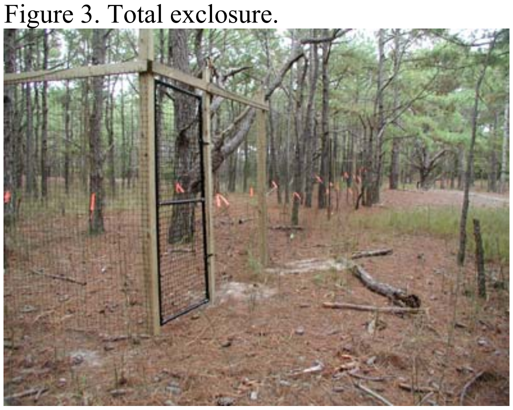


Figure 4. Partial exclosure.

Each Partial exclosure was constructed with reinforced corners where three fence posts were set at a right angle and connected near the top with an 8' board or post. Additional fence posts were set at ten meter intervals around the perimeter of the exclosure and in other areas as needed in order to compensate for changes in topography.

In the interest of encouraging deer to enter Partial treatment areas while at the same time successfully excluding horses, a minimal number of two high tension wires were initially strung. However, during the spring 2003 round of pin-sampling it was discovered that on two separate occasions a horse had gained entry into a Partial exclosure. In response to this, all Partial exclosures were reinforced with a third wire. The three wires were strung at approximately 0.4m, 0.75m, and 1.1m. This design successfully excluded horses while allowing deer access to the treatment area. See Figure 4.

Control Treatment

Control treatment areas were established at each study site. Like other treatments these areas measured 20m x 30m. Control treatment areas were continually exposed to both horse and deer herbivory throughout the study.

Vegetation and Habitat Monitoring

At each study site treatment areas were subdivided into twenty-four 5m x 5m sections. The corners of each section were marked by wooden stakes so that data collectors could orient themselves and navigate to sample locations within each treatment. Section columns were labeled A to F and rows I to IV. Each section was further subdivided into twenty-five 1m x 1m sub-sections, labeled columns: *a* to *e* and rows: *1* to *5*. Finally the sub-sections were further subdivided into sixteen 25cm x 25cm sampling-segments numbered 1 through 16. See Figure 5 for a detailed diagram of this sampling hierarchy.

Each year during 2003, 2004 and 2005, four rounds of data collection were conducted. These included spring and summer rounds of pin-sampling, a summer round of cover board sampling and a late winter round of browse sampling. During pin and browse sampling plant taxa were typically identified to species, however throughout the study some taxa with similar growth characteristics were difficult to consistently identify to species. In such instances these species were combined into plant taxonomic groups at the genus level. In the results section, the various species that are known to have composed a portion of a given plant taxonomic group are listed. All data were entered in Excel®.

Pin-Sampling

Pin-sampling is a commonly used vegetation sampling method (Elzinga, et al 1998). For this study the sampling-pin was designed to sample the vegetation between 0 and 1.5 meters above the ground, which roughly corresponds to the range in height where the vast majority of deer herbivory occurs. Also, as recommended by Elzinga, et al (1998) the sampling–pin was designed to pass through the vegetation at an angle other than perpendicular to the ground, here approximately 35 degrees, in order to increase the likelihood of contacting infrequent or rare species. The following paragraphs describe how study treatment areas were pin-sampled, see Figures 5 and 6.

Figure 5. Diagram of project sampling hierarchy.

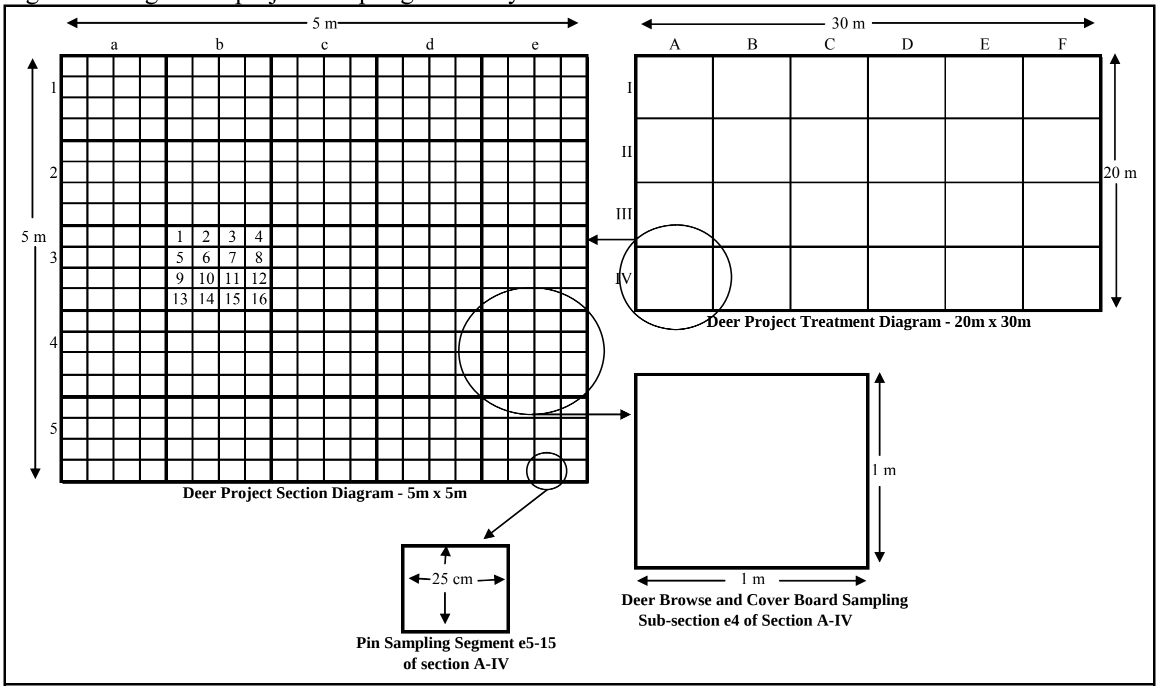
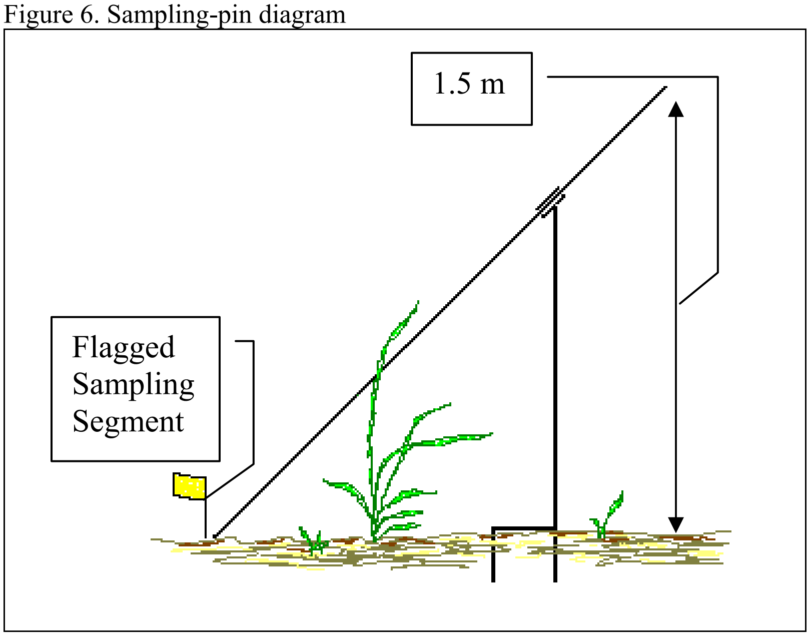


Figure 6. Sampling-pin diagram



During each year of this study (2003, 2004, 2005) pin-sampling occurred twice during the growing season, first in the spring (May-June) and again in the summer (August-September) in order to adequately sample both early and late season vegetation. During the summer of 2003 a change in personnel necessitated a longer sampling period, which was extended into October.

During each round of pin-sampling, twelve of the twenty-four 5m² sections in each treatment area were sampled at an intensity of twelve pins per section. In order to evenly distribute the sampling effort across the entire treatment area, a systematic sampling process was adopted. During each pin-sampling round, the sections to be sampled within each treatment were determined first by randomly selecting either section A-I or A-II, then by systematically sampling every other section. For example if A-I was chosen, then the twelve sections to be sampled were A-I, A-III, B-II, B-IV, C-I, C-III, D-II, D-IV, E-I, E-III, F-II and F-IV. This systematic sampling process distributed the sampling effort evenly across each treatment area during each round of pin-sampling.

Within each section to be sampled twelve random sample-segment locations were generated using the random number generator in Excel®. Each of the twelve selected sampling-segments was navigated to and flagged for sampling, see Figure 5. The observer then randomly determined a bearing at which to place the sampling-pin. The sampling-pin was then placed in the direction of the indicated bearing so that it touched the ground inside the flagged sampling-segment. Therefore, for a given treatment area, a round of pin-sampling included 12 systematically sampled 5m² sections, with each of these being pin-sampled at twelve random sample-segment locations. This resulted in a total of 144 sampled pins per treatment per round of data collection.

Figure 7. Relative abundance, richness, Shannon diversity and evenness formulas

$$RA = p_i = n_i \Big/ \sum_{i=1}^{S} n_i \qquad J = \frac{H'}{H'_{\max}} = \frac{-\sum_{i=1}^{S} p_i(\ln p_i)}{\ln S}$$

$$AA = n_i / T \qquad H' = -\sum_{i=1}^{S} p_i(\ln p_i)$$

In the above equations:

RA is **relative abundance**
AA is **absolute abundance**
p_i is proportional abundance of the *ith* species
n_i is the number of pin contacts by the *ith* species
S is **richness** or the total number of species contacted
J is equitability or **evenness**
T is the total number of pins
H´ is **Shannon diversity** index

The height of vegetation pin contacts were recorded in centimeter increments. In forest study sites all pin contacts were recorded. In shrub study sites the number of pin-contacts were substantially higher. This complicated data collection because it was frequently necessary to move vegetation in order to adequately observe the pin. Therefore in shrub study sites, only contacts that occurred on a predetermined half-moon circumference side of the pin were recorded. Which side was allowed to vary depending on observer preference, however each observer only sampled their preferred side of the pin. This facilitated accurate data collection by allowing observers, when necessary, to carefully move the vegetation not being sampled in order to adequately expose and record the contacts that were sampled.

The pin contact data was used to generate relative abundance (RA), absolute abundance (AA), species richness (S), Shannon diversity (H´) and evenness (J) estimates for each sampled section as well as for the overall treatment area. The equations for these vegetative parameters are shown in Figure 7.

<u>Browse Data Collection</u>

Data were collected each year (2003, 2004, 2005) during the second half of March in order to quantify the browse intensity experienced within the Partial and Control treatment areas. Here, following a methodology similar to Strole and Anderson (1992), 40 $1m^2$ quadrats (i.e. sub-sections, see Figure 6) were randomly located within each sampled treatment area. During sampling each quadrat was outlined by a $1m^2$ PVC frame and all stems or branches with a diameter greater than 8mm (roughly pencil thickness) were observed to a height of 1.5 m. Generally, this stem diameter seemed to perform well at allowing the observer to keep track of sampled stems. Each observed stem was identified and recorded as being browsed or unbrowsed.

Most potential browse plants were identified to species, however *Morella cerifera* and *M. pensylvanica* were combined into one *Morella* spp. category. Additionally, some browse species did not conform well to the greater than 8mm stem diameter criterion. In particular *Rubus* spp, *Smilax rotundifolia*, and *Toxicodendron radicans* were observed during browse sampling but rarely with a stem diameter greater than 8mm. Therefore the following adjustments were adopted during browse sampling for these species.

Figure 8. Cover-board sampling.

During each round of browse sampling all *Rubus.* spp and *S. rotundifolia* stems with a diameter greater than 5mm were recorded. The same was true for *T. radicans* during 2004 and 2005, however during 2003 all *T. radicans* occurrences, regardless of stem diameter, were recorded. This resulted in an elevated number of *T. radicans* browse observations in 2003. In order to correct this inconsistency in the data, a ratio of the total number of *T. radicans* stems to those stems with a diameter greater than 5mm was calculated during 2005 which was found to be approximately 10 to 1. Therefore, during analysis, the 2003 *T. radicans* browse data were divided by ten in order to transform these data, so that they conformed to data from subsequent years.

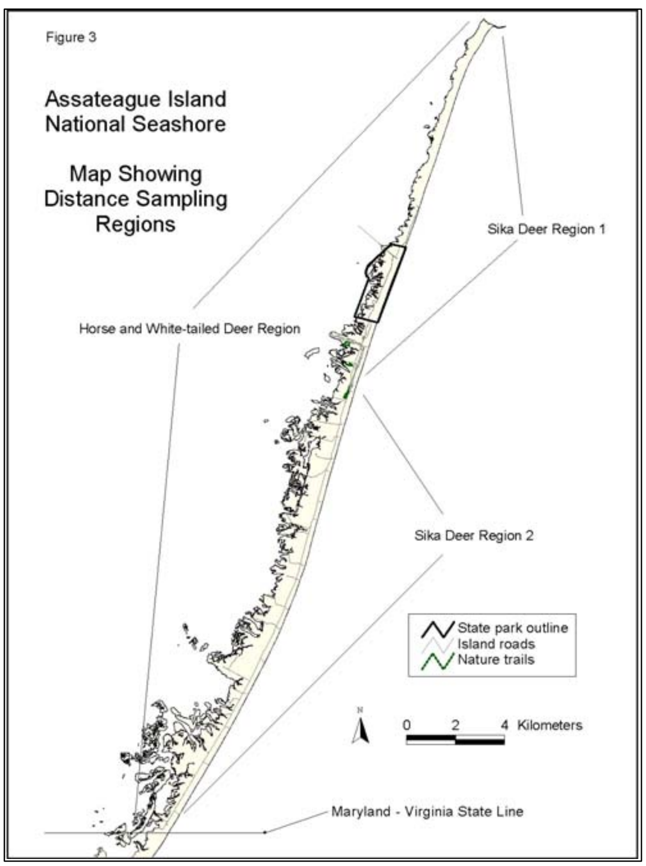
Cover-board Data Collection

Following Nudds (1977), a cover-board was used to estimate habitat density within each treatment area during each year of this study (2003, 2004, 2005). The cover-board measured 2m x 0.5m and was divided into four 0.5m² segments which were then subdivided into twenty five 10cm² squares. Within each treatment area, the board was placed in 30 randomly selected 1m² sub-sections (see Figures 6 and 8) and then randomly oriented within the bounds of having to face inside the treatment area. The observer then walked 10m perpendicular to the board, turned to face the board and from at an eye height of 1m (in order to monitor habitat cover from the approximate height of a deer) recorded the number of squares not covered by vegetation within each of the cover-board's 0.5m² segments. These data were collected during July.

Distance-sampling

Each winter from 2003 to 2006 distance-sampling was conducted on both deer populations throughout the Maryland end of Assateague Island, including both National Seashore and State Park areas. Together these areas encompass approximately 3620 hectares. Each year sampling occurred after the deer hunting season in February, which is believed to be when both deer populations are at their lowest yearly levels, since it occurs immediately after the hunting season yet before the birthing season.

Figure 9. Map of different island regions



A census of the horse population on the Maryland end of Assateague is conducted several times a year by park staff as part of the ongoing fertility control program (Kirkpatrick 1994). As a result, the size of the horse population is relatively certain at any given time. Therefore, while conducting distance transects, we also collected data on the horse population in order to test the validity and effectiveness of using distance-sampling at Assateague Island.

During the analysis of distance-sampling data for both horses and white-tailed deer, the entire Maryland end of Assateague Island was considered one region, since generally speaking management of these species did not change throughout the region. During 2003 the sika deer distance-sampling data were analyzed by stratifying the

Maryland end of Assateague Island into two regions which corresponded to the northern most sixteen kilometers (region 1 - approximately 999 hectares) and the southern most nineteen kilometers (region 2 – approximately 2621 hectares) see Figure 9.

Region 1 sika deer were initially believed to be generally more acclimated to humans since they inhabit the developed section of island which is heavily visited by the public. They are often fed (against regulation) by visitors and, until 2004, were not typically subjected to annual hunting pressures. However since 2004, region 1 sika deer have been subjected to an annual archery hunt and as a result their behavior has been observed to be similar to that of region 2 sika deer. Region 2 sika deer inhabit the less developed areas of the island and are subject to significant annual hunting pressures, including bow, muzzleloader and shotgun seasons.

It was believed at the onset of this project that this increased hunting pressure and lack of repeated exposure to park visitors conceivably caused region 2 sika deer to exhibit more cautious behaviors when encountering humans in the field, which in turn arguably caused the detection rates of sika deer between the two regions to differ. However after conducting this project for several years, it is the general consensus of observers that region 1 and region 2 sika deer typically exhibited similar behaviors when encountered in the field, with the exception of those relative few instances when sika deer were encountered along established park roads and pathways, where they apparently expect to see visitors. Since region 1 sika deer tended to exhibit behaviors similar to those of region 2, beginning in 2004 the entire Maryland end of Assateague Island was considered to be one region for the purposes of analyzing sika deer distance-sampling data.

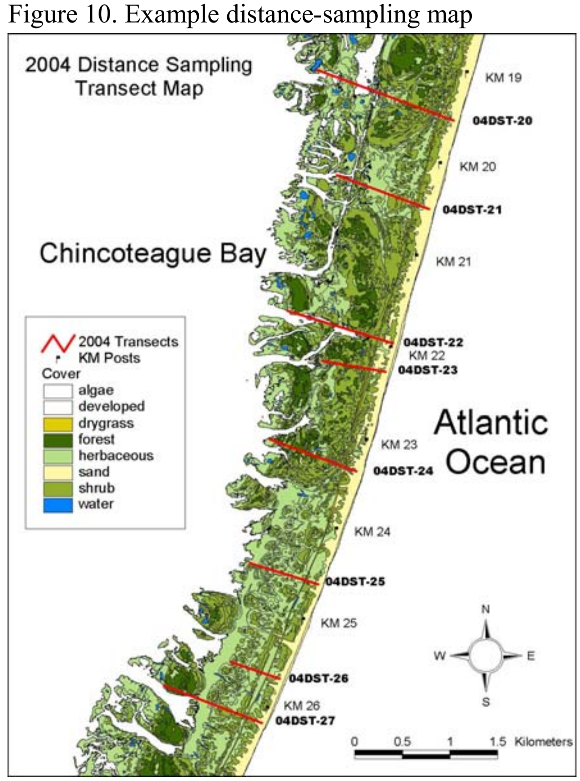
<u>Transects</u>

Each year thirty-five cross-island transects were established on the Maryland end of Assateague Island. The transects were stratified, one per kilometer of ocean front beach, starting with km 1 near the Ocean City inlet and continuing south to km 35 near the Maryland-Virginia state line.

The seaward starting point for each stratified transect was randomly located and the cross-island transect was established by following a bearing perpendicular to the island's north-south axis. As an example, Figure 10 shows the location of the 2004 distance-sampling transects along the section of island between kilometers 19 through 27.

Along each transect, a path wide enough for one person was cleared of vegetation and dead material. The density of some of

Figure 10. Example distance-sampling map



Assateague' habitats frequently made this task difficult. However establishing these transects allowed us to survey all island habitats at the approximate frequency at which they occur on Assateague, given the stratified random design of this project. Sometimes we were obligated to go around obstacles such as water guts or mosquito ditches. In such instances we detoured off the transect line a short distance and then returned to it once the obstacle was overcome.

Each transect was flagged with biodegradable paper flagging, and the start and end locations were recorded in real-time using a Trimble® Pro XR, Magellan® 3000 XL or Garmin® GPSMAP 76CS global positioning system (GPS). Later ArcView® 3.3 or ArcGIS® Geographic Information System (GIS) software were used to develop a map of transect locations. Each year after the transects were established, they were not surveyed for a minimum of one week (in most cases over three weeks) in order to allow resident horse and deer to become acclimated to them.

A literature review of sika and white-tailed deer behavior from both Assateague Island and mainland populations revealed the best time to conduct distance-sampling transect surveys was likely during late afternoon, when winter activity patterns increased for both species, after a typical midday period of low activity. Additionally, distance-sampling was only conducted under good weather conditions. Weather conditions such as excess wind (>10mph), rain, fog or snow sometimes caused the cancellation of data collection.

Observer Training

During this project, many different observers assisted with collecting both the vegetation and distance-sampling data. Prior to collecting data, observers were trained in proper data collection procedures.

In preparation for the various types of vegetation sampling this training included learning to identify the predominant vegetation within study sites by scientific name. It also entailed learning how to move about within study sites so as to minimize observer impacts, (walking lightly, paying close attention not to disturb areas to be sampled, etc.). Study site training also included procedures for proper sampling-pin, cover-board and quadrat placement, in order to limit opportunities for observer bias to occur. Observers also learned how to document unknown specimens using a label and numbering system. This system allowed unknown observations to be recorded in the field and later corrected after the taxa had been identified in the lab. Sample specimens of unknown taxa encountered during sampling were always collected outside of study areas and only in the presence of many other specimens, otherwise photographs and written physical descriptions were used.

Prior to each round of distance-sampling, a classroom training session was conducted in order to train new observers about basic sampling concepts and data collection procedures. Typically these sessions also served as a review for returning observers. The training session was developed using materials provided during a distance-sampling workshop developed by the USGS Patuxent Wildlife Research Center and the State University of New York College of Environmental Science and Forestry.

The subjects covered during this training session include compass and laser range finder use, how to distinguish between white-tailed and sika deer in the field, how to determine cluster size, how to walk a transect and what complementary data to collect whenever possible. The complementary data include such things as sex, life stage, habitat use and behavior of observed deer.

Prior to the commencement of data collection observers also participated in several practice transect surveys in an attempt to maintain data consistency and minimize observer bias. Here all data collection procedures were revisited and many possible field scenarios were discussed. Finally, during the first week of data collection, new observers accompanied experienced observers in the field, in order to refine data collection skills and assure good field techniques. After a new observer was deemed capable, he/she was then allowed to conduct transects alone.

Data Analysis

The experiment-wise error rate (α_e) used during all analyses was 0.05. Additionally, for all analyses the results of post-hoc procedures were protected against Type I error by using a comparison-wise error rate (α_c) as determined by $1 - \alpha_e = (1 - \alpha_c)^k$ where *k* equaled the number of groups. Analysis of Similarity (ANOSIM) and Similarity Percentage Analysis (SIMPER) procedures were conducted using PRIMER® v6. ANOVA and Tukey analyses were performed using SYSTAT® 11 statistical software. Chi-square analyses were conducted using Excel®.

<u>Pin-sampling – Species Abundance and Diversity Parameters</u>

Absolute abundance (AA), relative abundance (RA), species richness (S), evenness (J) and Shannon species diversity (H´) estimates were generated for the twelve sections sampled within each treatment during each round of sampling. AA was used to analyze individual species abundance responses to research treatments.

ANOSIM is a non-parametric, multivariate permutation procedure that analyzes both species composition and abundance and is considered a non-parametric analog to Multivariate Analysis of Variance (MANOVA). ANOSIM calculates a similarity matrix to evaluate within and between distance similarities between groups (treatment levels or years) of data. ANOSIM uses the Global R test statistic and also generates a level of significance for the Global R (a p-value). The Global R ranges from -1 to 1. A Global R of 1 indicates that all replicates within sites or treatments are more similar to each other than any replicates from different sites or treatments, or in other words the communities are completely dissimilar. A Global R of approximately 0 indicates that the null hypothesis of no difference is true, so that similarities between and within sites or treatments will be the same on average, or in other words the communities are the same.

ANOSIM analyses were conducted using RA estimates. Spring and summer round data were analyzed separately as were data from forest and shrub habitats. RA data were not transformed and the Bray-Curtis similarity measure was used for matrix construction. The number of permutations used was 99,999. ANOSIM data were pooled and within each treatment (Total, Partial and Control) comparisons were made between years (2003 v. 2004 v. 2005). Other ANOSIM analyses compared treatments after pooling data from all years, see Table 1. Significant ANOSIM results were further investigated by conducting pair-wise comparisons and SIMPER analyses. A brief description of each of these statistical procedures follows.

Table 1. ANOSIM comparisons

ANOSIM Comparisons	
Treatment	Year(s)
Control	2003 v. 2004 v. 2005
Partial	2003 v. 2004 v. 2005
Total	2003 v. 2004 v. 2005
Total v. Partial v. Total	2003 to 2005 combined

Since more than two groups existed for each ANOSIM analysis, in addition to the Global R, separate R-statistics were also generated for all pair-wise comparisons. This is similar to multiple comparison post-hoc tests. When presented, the R Statistic can be interpreted in a manner similar to that of the Global R above. Any significant pair-wise comparisons were further analyzed using the Similarities Percentage (SIMPER) procedure to determine the amount of contribution by individual species to the observed difference between groups of samples. The SIMPER procedure generates a list of species and their percent contribution to the overall dissimilarity between sample groups.

Experiment-wise multifactor analyses of variance (ANOVAs) were performed on S, H´, J, and AA estimates. Spring and summer round data were analyzed separately as were data from forest and shrub habitats. For each of these analyses potential sources of variation included years - (2003, 2004, 2005), treatments - (Total, Partial and Control) and four replicate study sites within both the forest or shrub habitats. Standard underlying assumptions applied. Specifically, regarding the analyses of AA data, it was assumed that for any given plant taxa random samples were drawn from a normal population and that the number of replicates was sufficient for sample means to conform to a normal distribution.

When experiment-wise ANOVA analyses rejected the null hypothesis, indicating a possible significant difference across independent variables or their interactions, protected, post-hoc ANOVA and Tukey tests were performed.

<u>Pin Sampling – Species Height</u>

Experiment-wise multifactor ANOVAs were conducted with potential sources of variation including years and treatments. Data from spring and summer were analyzed independently as were data from forest and shrub habitats. Standard assumptions applied.

Height data were collected randomly and it was assumed that site did not influence data variation. Given the stochastic nature of the distribution of individual plant taxa within each study site and the random placement of the pin within each sampled section, disproportionate replication occurred between years and treatments, resulting in some taxa having few or no observations recorded for specific year/treatment categories. As a result, height data analyses were restricted only to those taxa with adequate replication in all experiment-wise year/treatment categories.

For those plant taxa with sufficient height data replication, when experiment-wise ANOVAs rejected the null hypothesis, protected , post-hoc ANOVAs and Tukey tests were performed.

Browse

Chi-square (X^2) analyses were conducted on the browse data. Forest and shrub habitats were analyzed separately. Each year data were pooled by treatment between study sites during these analyses. Standard assumptions applied.

Given the stochastic nature of the distribution of individual plant taxa within each study site and the random placement of the $1m^2$ browse sampling quadrat within each treatment area, disproportionate replication occurred between years and treatments. As a result, some taxa had few or no observations recorded for specific year/treatment categories therefore chi-square analyses on individual browse species were restricted to those taxa with adequate replication in all experimental year/treatment categories. The proportion of browsed stems is presented by species for each year/treatment category along with the number of sampled stems.

Cover-board

Chi-square (X^2) analyses were conducted on the cover-board data. Forest and shrub habitats were analyzed separately. During these analyses each year's data were pooled by treatment between study sites. Standard assumptions applied.

Distance-sampling

Each year distance data were analyzed using the current version of the Distance® program. For each transect, sampling effort was proportional to transect length, therefore total sampling effort equaled the sum total length of all transects for each year. During data analyses, uniform and half-normal key functions were used in conjunction with cosine, simple polynomial and hermite polynomial series expansions.

Results and Discussion

Preliminary Study Site Selection

The name and location of each study site is shown in Figure 2, which also describes each site as occurring in forest or shrub habitats. Table 2 below shows the proportional similarity (PS) and heterogeneity (PD) between treatment areas at each selected study site found using the preliminary round of pin-sampling data.

Table 2. Study site proportional similarity (PS) and heterogeneity (PD) between treatments (Total, Partial and Control) calculated using preliminary data collected prior to exposure to study treatments.

Preliminary Deer-Vegetation Study Site - Bray-Curtis Proportional Similarity and Heterogeneity							
Habitat	Study Site	Proportional Similarity (PS)			Heterogeneity (PD)		
		Tot v Par	Tot v Con	Par v Con	Tot v Par	Tot v Con	Par v Con
Forest	FHNG	0.68	0.66	0.82	0.32	0.34	0.18
	F27N	0.72	0.68	0.64	0.28	0.32	0.36
	F27S	0.72	0.73	0.68	0.28	0.27	0.32
	FGRN	0.61	0.68	0.71	0.39	0.32	0.29
Shrub	SHNG	0.72	0.78	0.68	0.28	0.22	0.32
	SH20	0.83	0.83	0.84	0.17	0.17	0.16
	SH31	0.75	0.77	0.74	0.25	0.23	0.26
	SH34	0.71	0.73	0.71	0.29	0.27	0.29

Species Richness, Evenness and Diversity Analyses Results and Discussion

Table 3 presents the mean, standard error and sample size of S, J and H' estimates, calculated for each habitat, round, treatment and year category as well as over all years combined. Table 4 presents the significant results of the ANOVA and Tukey analyses that were conducted using the S, J and H' estimates. For each significant result, the mean value of the diversity parameter in question, its standard error and sample size are presented.

Tukey test pair-wise comparison probabilities range between 0 (completely different) and 1 (exactly the same). As an example consider Table 4 which shows that during the summer sampling round in forest study sites species richness (S) over all years combined was significantly higher in Total and Partial treatment areas as compared to Control treatment areas. Recall that Total treatment areas excluded all ungulates while Partial treatment areas excluded only horses and Control treatment areas allowed herbivory by all island ungulates. Given this experimental design, we can interpret the significant Tukey pair-wise comparison results as being primarily attributable to either horse or deer herbivory. For example, further considering the significant result mentioned above, because deer herbivory did not cause Partial treatment areas to exhibit significantly lower S values in comparison to Total treatment areas, we conclude that this result was primarily driven by horse herbivory, as indicated by the last column in Table 4.

Table 3. Mean species richness (S), evenness (J) and diversity (H') along with standard error and sample size (n) presented by habitat and sampling round for each year as well as over all years combined.

Habitat	Sampling Round	Year	Treatment	Mean			Standard Error			n
				S	J	H'	S	J	H'	
Forest	Spring	2003	Total	2.79	0.649	0.728	0.23	0.053	0.074	48
			Partial	2.90	0.619	0.730	0.26	0.053	0.079	48
			Control	2.69	0.645	0.693	0.20	0.053	0.069	48
		2004	Total	3.60	0.703	0.890	0.28	0.039	0.065	48
			Partial	3.06	0.634	0.749	0.24	0.053	0.072	48
			Control	3.06	0.696	0.793	0.19	0.043	0.060	48
		2005	Total	3.42	0.725	0.889	0.27	0.039	0.064	48
			Partial	3.00	0.599	0.744	0.26	0.055	0.078	48
			Control	2.54	0.595	0.639	0.17	0.054	0.066	48
		2003 - 2005	Total	3.27	0.692	0.835	0.15	0.026	0.039	144
			Partial	2.99	0.617	0.741	0.15	0.031	0.044	144
			Control	2.76	0.645	0.709	0.11	0.029	0.038	144
	Summer	2003	Total	3.88	0.738	0.979	0.36	0.040	0.075	48
			Partial	3.38	0.639	0.815	0.26	0.049	0.076	48
			Control	2.65	0.625	0.672	0.19	0.051	0.062	48
		2004	Total	3.71	0.710	0.923	0.24	0.035	0.069	48
			Partial	3.46	0.756	0.908	0.23	0.037	0.063	48
			Control	2.94	0.557	0.668	0.24	0.051	0.073	48
		2005	Total	4.44	0.697	0.967	0.36	0.038	0.065	48
			Partial	4.15	0.641	0.889	0.30	0.037	0.066	48
			Control	3.04	0.614	0.681	0.19	0.042	0.058	48
		2003 - 2005	Total	4.01	0.715	0.957	0.19	0.022	0.040	144
			Partial	3.66	0.679	0.871	0.16	0.024	0.040	144
			Control	2.88	0.599	0.674	0.12	0.028	0.037	144
Shrub	Spring	2003	Total	7.71	0.804	1.598	0.45	0.017	0.07	48
			Partial	6.69	0.825	1.471	0.44	0.02	0.072	48
			Control	7.69	0.819	1.615	0.48	0.022	0.081	48
		2004	Total	6.25	0.763	1.336	0.39	0.027	0.074	48
			Partial	6.60	0.766	1.409	0.43	0.024	0.076	48
			Control	6.77	0.83	1.473	0.47	0.014	0.066	48
		2005	Total	7.71	0.777	1.554	0.44	0.025	0.074	48
			Partial	7.10	0.769	1.448	0.48	0.023	0.076	48
			Control	7.13	0.786	1.491	0.40	0.017	0.065	48
		2003 - 2005	Total	7.22	0.781	1.496	0.25	0.013	0.043	144
			Partial	6.80	0.787	1.443	0.26	0.013	0.043	144
			Control	7.19	0.811	1.526	0.26	0.011	0.041	144
	Summer	2003	Total	8.38	0.76	1.555	0.49	0.019	0.071	48
			Partial	8.17	0.759	1.562	0.43	0.021	0.072	48
			Control	8.43	0.765	1.577	0.52	0.019	0.076	48
		2004	Total	7.06	0.818	1.536	0.37	0.015	0.059	48
			Partial	6.40	0.777	1.386	0.44	0.02	0.071	48
			Control	7.02	0.779	1.464	0.42	0.016	0.063	48
		2005	Total	9.02	0.74	1.575	0.56	0.022	0.074	48
			Partial	9.33	0.778	1.674	0.63	0.022	0.078	48
			Control	8.94	0.75	1.581	0.56	0.019	0.071	48
		2003 - 2005	Total	8.15	0.773	1.555	0.28	0.011	0.039	144
			Partial	7.97	0.771	1.541	0.31	0.012	0.043	144
			Control	8.14	0.765	1.541	0.30	0.01	0.04	144

Table 4. ANOVA and Tukey* test results of species richness (S), evenness (J) and diversity (H') estimates over all years combined (2003-2005). For each sampling round, study site, taxa and treatment category the mean, standard error and sample size (n) are presented. The final column indicates whether the results were primarily driven by horse or deer herbivory.

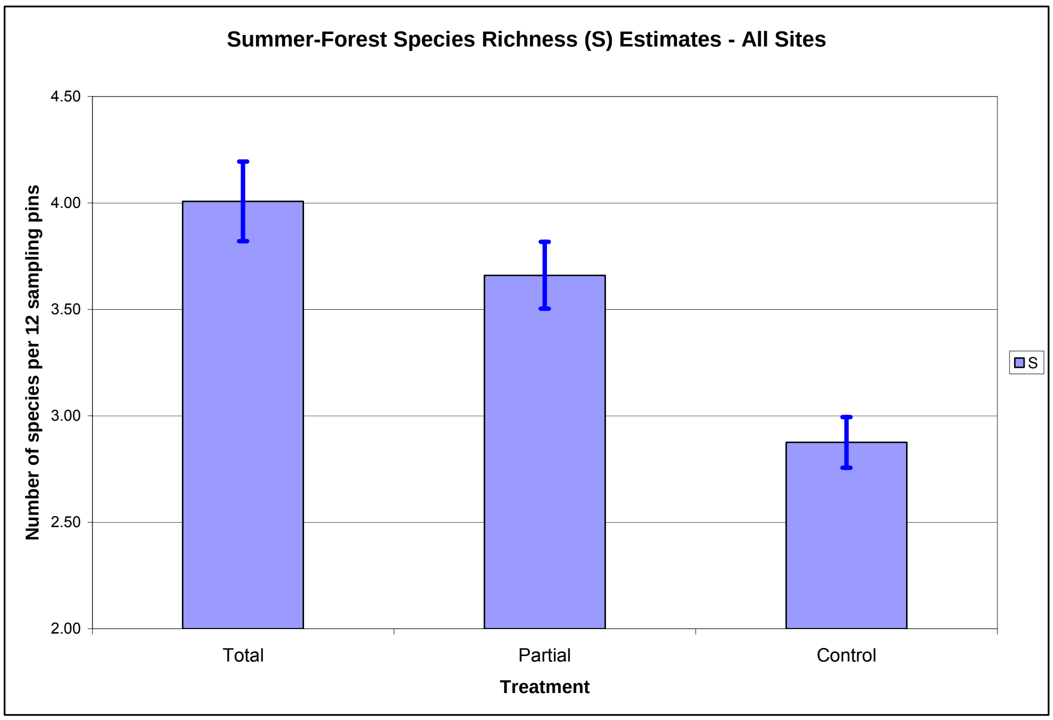
Habitat	Sampling Round	Study Site(s)	Diversity Parameter (S, J, H')	Treatment	Mean	Standard Error	n	Posthoc ANOVA p-value	Tukey Test Results Pairwise Comparison Probability		Horse or Deer?
Forest	Spring	FGRN	S	Total	4.83	0.36	36	0.000	Total - Partial	0.990	Horse
				Partial	4.78	0.27	36		Total - Control	0.001	
				Control	3.36	0.21	36		Partial - Control	0.002	
			H'	Total	1.20	0.07	36	0.003	Total - Partial	0.726	Horse
				Partial	1.27	0.06	36		Total - Control	0.029	
				Control	0.96	0.06	36		Partial - Control	0.003	
	Summer	All Comb-ined	S	Total	4.01	0.19	144	0.000	Total - Partial	0.261	Horse
				Partial	3.66	0.16	144		Total - Control	0.000	
				Control	2.88	0.12	144		Partial - Control	0.001	
			J	Total	0.72	0.04	144	0.003	Total - Partial	0.551	Horse and Deer
				Partial	0.68	0.04	144		Total - Control	0.002	
				Control	0.60	0.04	144		Partial - Control	0.054	
			H'	Total	0.96	0.04	144	0.000	Total - Partial	0.266	Horse
				Partial	0.87	0.04	144		Total - Control	0.000	
				Control	0.67	0.04	144		Partial - Control	0.001	
		FGRN	S	Total	6.39	0.42	36	0.000	Total - Partial	0.423	Horse
				Partial	5.83	0.25	36		Total - Control	0.000	
				Control	3.14	0.24	36		Partial - Control	0.000	
			H'	Total	1.42	0.06	36	0.000	Total - Partial	0.456	Horse
				Partial	1.32	0.06	36		Total - Control	0.000	
				Control	0.78	0.07	36		Partial - Control	0.000	
		FHNG	H'	Total	0.85	0.06	36	0.001	Total - Partial	0.268	Horse
				Partial	0.70	0.06	36		Total - Control	0.001	
				Control	0.48	0.07	36		Partial - Control	0.054	

* see page 16 for an explanation of Tukey test results.

Herbivory is reducing species richness (S), evenness (J) and diversity (H') in Assateague Island's maritime forest habitats. Figures 11, 12 and 13 graphically present the S, J and H' results from the analyses of summer-forest data. According to these results, horse herbivory is primarily responsible for lowering S and H'. As can be seen in Figures 11 and 13, Control treatment areas had significantly lower mean S and H' estimates as compared to both Partial and Total treatments. J was also affected by herbivory, however the analysis revealed that at the $\alpha_e = 0.05$ confidence level, its reduction was due to the combined effects of both horse and deer herbivory (J Partial-Control pair-wise comparison probability = 0.054, J Total-Control pair-wise comparison probability = 0.002). Also of interest is the fact that in all three graphs Partial treatment areas consistently produced lower S, J and H' estimates, though not significantly so, than Total treatment areas. This consistency seems to indicate that the current level of deer herbivory is also contributing to the lower S, J and H' estimates observed during the summer in Assateague's maritime forest habitats.

The intermediate disturbance hypothesis argues that biodiversity is highest at intermediate levels of disturbance, or herbivory in the context of this research. At low disturbance levels, as occurred in Total treatment areas, this hypothesis argues that diversity will begin to decline as a result of competitive exclusion by dominant plant species. At the same time the hypothesis argues that in the presence of excessive disturbance, analogs to Control treatment areas, species diversity declines because only species that can withstand this high level of disturbance persist. Thus, according to this hypothesis, sites that experience intermediate levels of disturbance, here Partial treatment areas, should exhibit higher levels of diversity. Although these results of do not appear to support this hypothesis, I would argue that the timeframe over which this project was implemented was not sufficiently long enough to adequately test it. Given a longer response time to project treatments, on the scale of years or decades, I believe the project's forested Total treatment areas would likely experience a decline in vegetative diversity, becoming dominated by a certain few perennial tree, shrub and vine species. To date the project's exclosures continued to be maintained in part, so that this hypothesis will be able to be adequately tested.

Figure 11. Bar graph of summer forest species richness (S) estimates. (S = number of species per 12 sampling pins) of Total, Partial and Control treatments +/- one standard error. Total and Partial S were significantly higher than Control S, but were not significantly different from one another (see Table 4).



No similar reduction of S, J or H' was revealed during data analyses for shrub habitats, although the existing level of ungulate herbivory did influence the abundance of individual species in shrub habitats on Assateague Island, see the species absolute abundance analyses results and discussion section.

Figure 12. Bar graph of summer forest species evenness (J) estimates of Total, Partial and Control treatments +/- one standard error. Total J was significantly higher than Control J, but was not so regarding Partial J. Additionally Partial J was greater than Control J at the 0.054 significance level which, although close, was not significant at $\alpha = 0.05$. (see Table 4)

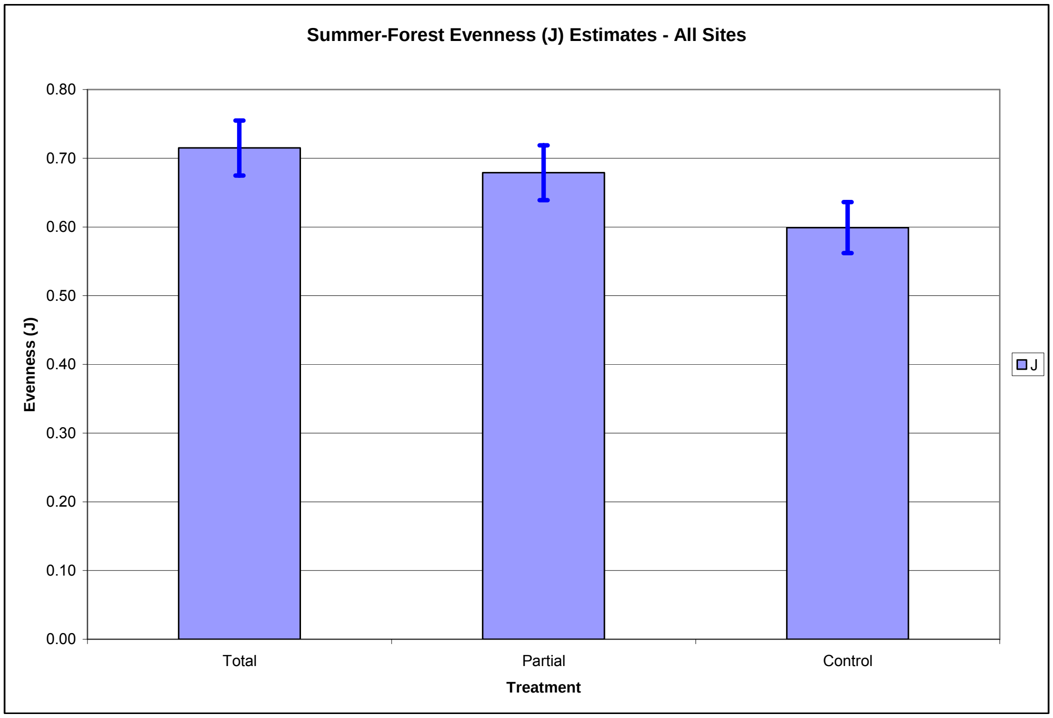
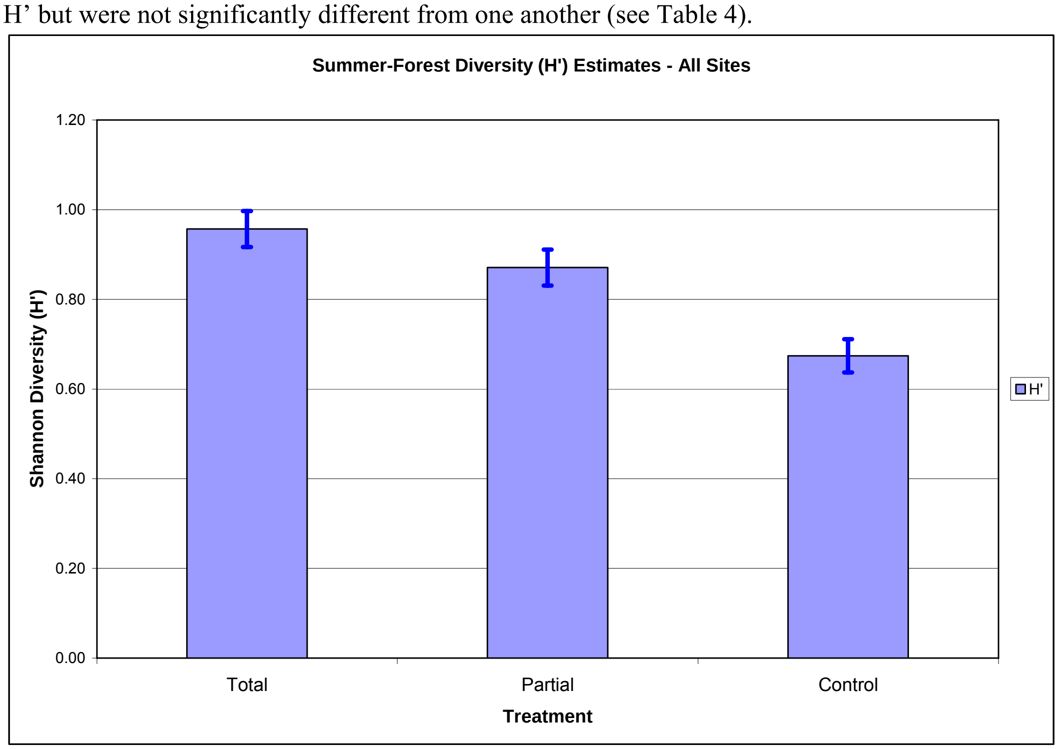


Figure 13. Bar graph of summer forest species diversity (H') estimates of Total, Partial and Control treatments +/- one standard error. Total and Partial H' values were both significantly higher than Control H' but were not significantly different from one another (see Table 4).



Species Relative Abundance

Tables 5 and 6 present the estimated relative abundance of each species or taxonomic group in both forest and shrub habitats.

Table 5. Forest study site relative abundance (RA, %) estimates for species (or taxonomic group) identified in each treatment after combining data within the spring or summer sampling rounds. RA estimates are shown for each year (2003, 2004, 2005) of the research project. Also shown are species common names and abbreviations (Species Abbrev) used during this research for each species (or taxonomic group).

			Forest																	
			Spring									Summer								
Species	Common Name	Species Abbrev	Control			Partial			Total			Control			Partial			Total		
			2003	2004	2005	2003	2004	2005	2003	2004	2005	2003	2004	2005	2003	2004	2005	2003	2004	2005
Acer rubrum	Red maple	ACRU	7.0	2.3	0.1	3.6	0.2		1.0	1.0	4.1	0.5	0.1	6.1	0.1		0.2	0.5	2.2	1.7
Amelanchier canadensis	Serviceberry	AMCA		2.5		0.2	1.5			0.3			0.1			1.2	0.1	0.3	0.1	
Ammophila breviligulata	American beachgrass	AMBR				0.4	1.7	0.8	0.2	0.4	0.1		0.3		0.7	0.1	0.1	0.7	1.0	0.1
Andropogon virginicus	Bluestem	ANVI									0.3		1.4	0.9	1.2	2.2	0.4	0.1	0.5	0.3
Carex spp.	Sedges	CASP	0.6			0.2	0.4	0.1	1.0	1.2	0.3	0.2	0.8	0.3	3.0	0.1	0.9	3.1	1.7	0.9
Chasmanthium laxum	Slender woodoats	CHLA	14.4	9.1	9.6	17.4	11.5	13.0	19.7	18.9	17.2	19.8	19.8	22.9	28.8	29.7	38.2	29.3	28.0	38.3
Cirsium vulgare	Bull thistle	CIVU														0.1				
Crataegus pruinosa	Hawthorn	CRPR							0.2											
Danthonia sericea	Downy danthonia	DASE				0.6					0.3						0.1			0.1
Dichanthelium acuminatum	Tapered rosette grass	DIAC				0.4	0.5	0.8	0.2	0.2	0.1			0.5	0.4	0.4	0.8	0.4	1.1	0.7
Digitaria filiformus	Slender crabgrass	DIFI														0.1		0.1		
Diospyros virginiana	Persimmon	DIVI	0.9	4.0	1.6	0.4	3.2	0.1	2.7	0.8	0.7	3.2	2.4	3.3	0.3		1.5	1.3	0.5	1.3
Elephantopus nudatus	Smooth elephantsfoot	ELNU				1.0	0.1	0.3	0.2	0.6	0.6			0.2	0.9	0.7	0.3	1.5	0.9	1.2
Eragrostis spectabilis	Purple lovegrass	ERSP										0.5			2.8	1.3	0.2	1.7	0.7	0.3
Festuca rubra	Red fescue	FERU	1.7	2.0	5.5	3.7	2.5	9.3	2.3	1.0	3.7		0.5	1.6	0.1	1.8	4.7		1.3	2.2
Hieracium gronovii	Gronovis hawkweed	HIGR									0.1									
Hypericum gentianoides	Pinweed St Johnswort	HYGE					0.1													
Ilex opaca	American holly	ILOP	1.3	0.8	1.5	0.4	0.1	0.1				0.2	0.8	0.6						
Juncus dichotomus	Forked rush	JUDI				0.2		1.3	0.2	1.8	1.0				0.3	0.7	0.8	2.0	1.5	0.9
Juncus scirpoides	Needlepod rush	JUSC								0.1	0.3									
Nuttallanthus canadensis	Canada toadflax	NUCA																0.1		
Linum medium	Stiff yellow flax	LIME													0.4					
Liquidambar styraciflua	Sweetgum	LIST	0.6				0.2				0.6								0.2	0.1

Table 5 continued.

Species		Species Abbrev	Forest																	
			Spring									Summer								
			Control			Partial			Total			Control			Partial			Total		
			2003	2004	2005	2003	2004	2005	2003	2004	2005	2003	2004	2005	2003	2004	2005	2003	2004	2005
Mikania scandens	Climbing hempweed	MISC									0.1									
Mitchella repens	Partridgeberry	MIRE																0.1	0.1	0.1
Moss, lichen, or fungi	Moss, lichens or fungi	MLF		0.3	0.3	3.0	0.8	0.8	1.0		0.9		0.2	0.2	2.5	1.2	0.5	0.8		0.3
Morella spp.	Bayberry / Waxmyrtle	MOSP	9.3	8.3	5.8	7.1	6.7	3.2	3.5	2.1	1.4	12.0	8.5	5.4	8.9	3.1	1.9	2.7	2.6	2.0
Nyssa sylvatica	Blackgum	NYSY		0.1														0.3		
Onoclea sensibilis	Sensitive fern	ONSE							0.2	0.1	0.3								0.4	0.5
Panicum amarum	Bitter panicgrass	PAAM	0.2							0.1	0.3						0.5			0.7
Panicum virgatum	Switchgrass	PAVI	0.9	0.4	0.1	1.8	1.5	0.3		0.2	0.3	2.3	2.8	2.0	3.1	2.4	3.6	2.9	1.0	1.2
Parthenocissus quinquefolia	Virginia creeper	PAQU	0.6	0.9								0.2	0.2							
Pinus taeda	Loblolly pine	PITA	20.4	27.5	49.3	17.8	31.4	35.7	27.8	22.9	26.5	32.1	36.8	37.0	25.2	19.4	25.4	19.1	29.1	23.6
Prunus serotina	Black cherry	PRSE		0.3																
Sassafras albidum	Sassafras	SAAL																0.3		0.1
Schizachyrium scoparium	Little bluestem	SCSC										0.2						1.3	0.5	
Sisyrinchium atlanticum	Blue-eyed grass	SIAT				0.2														
Smilax bona-nox	Saw greenbrier	SMBO								0.3	0.7	0.2		0.1				0.1		0.3
Smilax glauca	Cat greenbrier	SMGL			0.1									2.3			0.2		0.1	0.8
Smilax rotundifolia	Greenbrier	SMRO	24.6	30.9	17.5	22.1	16.0	15.7	24.9	28.3	24.9	19.4	19.9	12.8	15.0	16.7	12.5	18.8	17.8	15.3
Spartina patens	Saltmeadow cordgrass	SPPA	0.9	0.5			7.9			1.8	0.9		0.9	0.8		10.1	0.9	0.1	0.4	0.1
Toxicodendron radicans	Poison ivy	TORA	10.2	6.4	4.9	13.8	9.5	6.8	8.9	7.0	5.1	5.0	2.0	1.2	3.3	3.7	1.7	4.9	3.0	2.7
Vaccinium corymbosum	Highbush blueberry	VACO	0.6	2.4	1.8	3.2	3.2	8.8	1.7	6.3	5.0	2.3	0.5	0.3	2.4	4.2	2.7	2.3	1.6	1.8
Vitis rotundifolia	Muscadine grape	VIRO	5.9	1.5	1.6	2.4	0.9	2.7	3.9	4.5	4.1	2.1	1.9	1.7	0.4	0.7	1.3	5.2	3.8	2.7
Vulpia octoflora	Sixweeks fescue	VUOC				0.4			0.2											

In Table 5 the taxonomic group listings included *Carex* spp., MLF and *Morella* spp. *Carex* spp. included *C. albicans*, *C. emmonsii*, *C. longii*, and *C. silicea* among other *Carex* species. MLF was used for all mosses, lichens and fungi contacted during sampling. *Morella* spp. included *M. cerifera* and *M. pensylvanica*. In forest study sites nearly all *Morella* spp. contacts were from *M. cerifera*.

Table 6. Shrub study site relative abundance (RA, %) estimates for species (or taxonomic group) identified in each treatment after combining data within the spring or summer sampling rounds. RA estimates are shown for each year (2003, 2004, 2005) of the research project. Also shown are species common names and abbreviations (Species Abbrev) used during this research for each species (or taxonomic group).

Shrub																				
			Spring									Summer								
Species	Common Name	Species Abbrev	Control			Partial			Total			Control			Partial			Total		
			2003	2004	2005	2003	2004	2005	2003	2004	2005	2003	2004	2005	2003	2004	2005	2003	2004	2005
Acer rubrum	Red maple	ACRU											0.1						0.1	
Agalinis purpurea	Purple false foxglove	AGPU											0.1	0.5		0.4	0.6		0.3	1.2
Agrostis stolonifera	Seaside bentgrass	AGST	1.0		0.1	0.8			0.2		0.2			0.1			0.4			0.2
Ammophila breviligulata	American beachgrass	AMBR	6.2	3.4	1.3	10.5	7.2	4.5	6.2	5.8	3.5	2.2	2.4	1.6	5.9	4.0	3.5	5.2	5.7	2.3
Andropogon virginicus	Broomsedge bluestem	ANVI	10.1	4.6	7.5	3.7	2.8	4.4	7.4	7.6	6.1	10.3	9.5	4.7	8.9	2.8	4.4	8.0	5.1	5.0
Aristida tuberculosa	Seaside threeawn	ARTU		0.0			0.4					1.6	2.7	2.2	3.3	1.5	1.7	2.8	0.9	1.7
Baccharis halimifolia	Eastern baccharis	BAHA	1.2	1.2	0.9	2.4	1.4	1.6	1.2	1.6	0.7	1.3	0.5	1.0	1.5	0.4	1.1	1.7	1.6	2.8
Bulbostylis capillaris	Densetuft hairsedge	BUCA											0.2	0.1		0.1			0.3	
Carex spp.	Sedges	CASP	0.2	1.1	0.6	0.1	2.7	1.0	0.3	0.4	0.6	0.1	0.1		0.0	0.1	0.1	0.3		0.1
Cenchrus tribuloides	Sanddune sandbur	CETR										0.1						0.0		
Chasmanthium laxum	Slender woodoats	CHLA			0.1							0.1	0.1	0.2						0.2
Cirsium horridulum	Yellow thistle	CIHO				0.1			0.4	0.1	0.1									
Cirsium vulgare	Bull thistle	CIVU																0.0	0.2	0.1
Conyza canadensis	Horseweed fleabane	COCA												0.1	0.0		0.4	0.1		0.2
Cyperus spp.	Nutgrass	CYSP									0.0	0.1	0.5	0.0	0.1	0.7	0.2		1.1	0.2
Dichanthelium acuminatum	Tapered rosette grass	DIAC	5.1	2.1	3.4	3.9	2.7	3.2	3.6	2.0	2.0	4.9	1.1	2.3	3.5	1.2	2.5	1.9	1.1	1.3
Digitaria filiformus	Slender crabgrass	DIFI											0.1							
Diodia teres	Poorjoe	DITE	0.1						0.1	0.1		0.1	0.5	0.1	0.0	0.1	0.1	0.1	0.1	
Diospyros virginiana	Persimmon	DIVI	0.3							0.5	0.5								0.2	0.0
Distichlis spicata	Marsh spikegrass	DISP	4.2	3.4	2.9	5.0	4.7	3.8	2.1	5.5	2.7	2.1	2.9	2.9	3.5	5.4	2.1	2.6	4.5	2.6
Drosera intermedia	Spoonleaf sundew	DRIN			0.1															
Eleocharis spp.	Spikerushes	ELSP	0.1	0.0	0.4	0.9		1.1	0.6		1.3				0.1		1.1	1.4		0.2
Eragrostis spectabilis	Purple lovegrass	ERSP						0.3			0.0	1.2	1.6	0.9	1.9	1.2	1.3	1.0	0.4	1.3
Eupatorium hyssopifolium	Hyssopleaf thoroughwort	EUHY	0.6	0.3	0.2		0.3	0.5	0.6	2.0	0.3	0.4	0.7	0.1	0.4	3.2	0.5	0.7	1.9	0.7
Eupatorium rotundifolium	Roundleaf thoroughwort	EURO				0.1			0.1		0.2			0.1			0.0	0.0		0.2
Euthamia tenuifolia	Slender goldentop	EUTE	0.3					0.6			0.9			0.2					0.3	0.2

Table 6 continued.

Species	Common Name	Species Abbrev	Shrub																	
			Spring									Summer								
			Control			Partial			Total			Control			Partial			Total		
			2003	2004	2005	2003	2004	2005	2003	2004	2005	2003	2004	2005	2003	2004	2005	2003	2004	2005
Festuca rubra	Red fescue	FERU	4.0	2.0	3.3	4.4	2.8	4.2	2.2	1.4	1.9	1.5	2.2	0.5	1.6	0.5	0.9	0.9	0.2	0.3
Fimbristylis autumnalis	Slender fimbry	FIAU													0.1					
Fimbristylis castanea	Marsh fimbry	FICA	1.0	1.0	1.1	2.6	2.2	0.4	2.6	1.1	1.3	0.4	1.5	0.7	3.3	5.8	2.1	4.3	1.7	1.9
Fuirena pumila	Dwarf umbrellasedge	FUPU											0.2	0.3		1.4	0.9		3.6	0.4
Galium hispidulum	Coastal bedstraw	GAHI						0.2												
Galium obtusum	Bluntleaf bedstraw	GAOB					0.1													
Gamochaeta purpurea	Spoonleaf everlasting	GAPU	0.2	0.1	0.2	0.2	0.0	0.2	0.1	0.2	0.3	0.0						0.1		
Hieracium caespitosum	Yellow hawkweed	HICA	0.1								0.2									
Hudsonia tomentosa	Sand-heather	HUTO	2.9	3.4	4.6	4.3	4.4	3.8	5.0	3.7	4.0	4.0	2.2	3.5	5.1	3.4	2.0	6.2	3.0	3.6
Hypericum gentianoides	Pinweed St Johnswort	HYGE	0.3	0.4	0.1	0.8	1.2	0.6	0.4	0.1	0.1	1.0	0.3	0.1	1.7	0.7	0.8	0.5	0.3	0.2
Hydrocotyle verticillata	Whorled pennywort	HYVE			0.1	0.1	0.6	0.2					0.4	0.4		0.3	0.3			0.0
Ipomoea spp.	Morningglory	IPSP												0.1						
Juncus dichotomus	Forked rush	JUDI	8.5	5.5	3.4	5.6	3.6	4.5	6.3	3.6	3.4	3.0	3.4	1.7	3.9	3.1	2.2	4.1	2.2	1.9
Juncus roemerianus	Black needle rush	JURO															0.0			
Juncus scirpoides	Needlepod rush	JUSC	1.5	0.8	2.1	1.9	2.1	1.9	1.1	0.6	1.0	1.6	1.4	1.2	2.1	1.5	1.6	0.7	1.3	1.0
Juncus spp.	Rushes	JUSP				0.1			0.1		0.0									
Krigia virginica	Virginia dwarfdandelion	KRVI						0.2									0.1			
Lechea maritima	Beach pinweed	LEMA		0.1	0.1		0.3	0.3			0.4	0.1	0.1	0.0	0.8	0.2	0.1	1.2	1.5	1.8
Linum intercursum	Sandplain flax	LIIN												0.1			0.2			0.0
Linum medium	Stiff yellow flax	LIME	0.1			0.3			0.1											
Lycopodiella appressa	Southern bog clubmoss	LYAP	0.1																	
Lythrum lineare	Wand lythrum	LYLI	0.2	0.1	0.2	0.5		0.7	0.6	0.1	0.3	0.1	0.4	0.6	0.4	0.4	1.4	1.1	1.0	1.9
Malus angustifolia	Southern crabapple	MAAN	0.1																	
Mikania scandens	Climbing hempweed	MISC				0.1					0.1		0.2	0.3		0.3	0.5		0.3	0.8
Moss, lichen, or fungi	Moss, lichens or fungi	MLF	0.1	0.1	0.1	0.1		0.2	0.1	0.1	0.8	0.1	0.2	0.4		0.1	0.2	0.2	0.1	0.2
Morella spp.	Bayberry / Waxmyrtle	MOSP	10.6	9.3	11.8	9.5	7.7	8.1	9.4	9.2	12.9	7.6	8.6	6.4	5.4	7.9	9.4	5.9	10.0	8.3
Nostoc spp.	Algea	NOSP	0.1		0.7				1.9		1.1	0.3		0.1			0.2			
Nuttallanthus canadensis	Canada toadflax	NUCA	0.1	0.0	0.1	0.6	0.0	0.1	0.2	0.1	0.1				0.2			0.4		

Table 6 continued.

Shrub																				
Species	Common Name	Species Abbrev	Spring									Summer								
			Control			Partial			Total			Control			Partial			Total		
			2003	2004	2005	2003	2004	2005	2003	2004	2005	2003	2004	2005	2003	2004	2005	2003	2004	2005
Panicum amarum	Bitter panicgrass	PAAM	0.9	0.4	0.4	2.1	0.2	0.4	2.3	0.6	0.9	0.2	1.1	1.3	0.4	0.8	1.3	1.5	0.4	1.9
Panicum virgatum	Switchgrass	PAVI	1.6	1.8	2.2	0.6	3.6	2.0	0.8	1.6	1.5	4.0	3.2	4.4	3.5	2.9	4.5	1.7	2.2	3.7
Parthenocissus quinquefolia	Virginia creeper	PAQU							0.1											
Phragmites australis	Common reed	PHAU	1.3	2.2	1.4	1.1	2.7	1.7	0.6	1.6	1.2	0.7	2.7	2.5	1.8	2.8	2.6	1.0	1.4	0.7
Pinus taeda	Loblolly pine	PITA	1.8	0.5	2.5	3.1	0.3	0.6	0.9			1.6	1.1	2.8			0.5	0.1		3.5
Pluchea odorata	Marsh fleabane	PLOD														0.1	0.1	0.2	0.1	0.0
Poa annua	Annual bluegrass	POAN							0.1											
Polygonella articulata	Coastal jointweed	POAR								0.0								0.1	0.1	
Polygonum punctatum	Dotted smartweed	POPU			0.1		0.3	0.7				0.1	1.0	0.1	0.2	0.5	1.1			
Prunus serotina	Black cherry	PRSE			0.1															0.1
Psuedognaphalium obtusifolium	Rabbittobacco	PSOB	0.2	0.0		0.1	0.1		0.4				0.2	0.0			0.1		0.2	
Ptilimnium capillaceum	Herbwilliam	PTCA		0.6	0.1		0.3	0.3		0.2	0.3						0.8			
Rhexia mariana	Maryland meadowbeauty	RHMA												0.1						
Rhus copallina	Dwarf sumac	RHCO									0.1							0.1		
Rhynchospora spp.	Beaksedge	RHSP	0.1											0.5						
Rubus spp.	Blackberry	RUSP	0.4	0.5	0.4	0.5	0.4	0.5	5.8	2.8	4.4	0.4		0.1	0.3	0.3	0.2	1.3	1.0	0.6
Rumex acetosella	Red sorrel	RUAC	0.3	0.6	0.5	0.3	0.8	0.9	0.8	1.5	0.6	0.0	0.1		0.0	0.2		0.4	0.1	
Sabatia stellaris	Rose of Plymouth	SAST																	0.1	
Samolus valerandi	Seaside brookweed	SAVA								0.2										
Schizachyrium scoparium	Little bluestem	SCSC										7.3	1.5	8.5	2.1	0.4	2.1	8.6	2.6	3.5
Schoenoplectus pungens	Common threesquare	SCPU	5.0	12.1	7.1	4.8	7.1	7.9	3.5	2.4	3.7	7.6	8.7	10.8	5.4	7.6	9.6	2.6	3.3	3.5
Scleria verticillata	Low nutrush	SCVE										0.2	0.3	1.7	0.9	0.3	1.8			0.5
Setaria parviflora	Marsh bristlegrass	SEPA										2.4	0.7	1.6	0.5	0.9	1.4	0.3	0.7	1.0
Sisyrinchium atlanticum	Eastern blue-eyed grass	SIAT	0.3	0.0	0.5	0.1			0.1		0.3			0.1	0.2					

Table 6 continued.

Species	Common Name	Species Abbrev	Shrub																	
			Spring									Summer								
			Control			Partial			Total			Control			Partial			Total		
			2003	2004	2005	2003	2004	2005	2003	2004	2005	2003	2004	2005	2003	2004	2005	2003	2004	2005
Smilax glauca	Cat greenbrier	SMGL	0.1		0.3			0.1	0.2	0.6	0.4			0.0					0.1	0.7
Smilax rotundifolia	Greenbrier	SMRO	0.1	0.0					0.3		0.8	0.0	0.4					0.1	0.5	0.3
Solidago sempervirens	Seaside goldenrod	SOSE	0.6	0.4	0.2	0.6	0.6	0.2	2.1	0.9	1.2	0.2	0.4	0.2	0.3	0.4	0.3	0.8	1.1	0.4
Spartina patens	Saltmeadow cordgrass	SPPA	18.2	33.8	28.9	22.2	32.4	33.1	16.8	32.3	23.3	28.8	33.0	28.0	29.1	34.3	29.0	26.6	33.7	31.9
Toxicodendron radicans	Poison ivy	TORA	7.9	5.6	6.4	5.3	3.5	4.9	7.5	6.3	8.7	0.6	1.1	1.3	1.1	1.3	1.4	1.1	1.0	2.2
Triplasis purpurea	Purple sand grass	TRPU														0.2	0.1			
Unknown forb 1	N/A	UNF1							0.1											
Unknown forb 5	N/A	UNF5					0.0													
Unknown forb 6	N/A	UNF6							0.1											
Unknown forb 12	N/A	UF12							0.2											
Unknown grass 2	N/A	UNG2			0.1															
Vaccinium corymbosum	Highbush blueberry	VACO	1.8	2.3	4.0	0.7	0.2	0.3	2.8	2.3	3.9	0.9	0.7	2.4	0.4	0.4	0.6	1.5	1.9	2.0
Vitis rotundifolia	Muscadine grape	VIRO		0.2				0.2	1.9	0.6	1.4	0.1	0.1				0.1	0.2	0.5	0.5
Vulpia octoflora	Sixweeks fescue	VUOC	0.2			0.3	0.1	0.2	0.2		0.2			0.0						0.1
Xyris torta	Yelloweyed grass	XYTO										0.0	0.2	0.1			0.0			0.0
Zizaniopsis miliacea	Giant cutgrass	ZIMI										0.2			0.2			0.1		

In Table 6 the taxonomic group listings included *Carex* spp., *Cyperus* spp., *Eleocharis* spp., *Ipomoea* spp., *Juncus* spp., MLF, *Morella* spp., *Nostera* spp., and *Rubus* spp. *Carex* spp. included *C. albicans*, *C. emmonsii*, *C. longii*, and *C. silicea* among other *Carex* species. *Cyperus* spp. included *C. filicinus* and *C. polystachyos*. *Eleocharis* spp. included *E. obtusa*, *E. palustris*, and *E. rostellatta*. *Ipomoea* spp. contacts were only identified to genus. *Juncus* spp. included *J. acuminatus*, *J. canadensis*, *J. effusus*, and *J. gerardii*, however it is important to note that *J. dichotomus*, *J. scirpoides* and *J. roemerianus* contacts were each identified to species and recorded separate from the *Juncus* spp. taxonomic grouping. MLF was used for all mosses, lichens and fungi contacted during sampling. *Morella* spp. included *M. cerifera* and *M. pensylvanica*. All fresh water cyanobacteria contacts were recorded as *Nostoc* spp. *Rubus* spp. included *R. argutus*, *R. cuneifolius*, and *R. flagellaris*.

Species Relative Abundance ANOSIM and SIMPER Results and Discussion

The SIMPER results shown in Tables 7 through 13 list the species that contributed to dissimilarity in community composition between specified treatments in their order of importance from greatest to least up to the eightieth percentile. The species or taxonomic group abbreviations found in these tables can be cross-referenced with the species or taxonomic group listings found in Tables 5 or 6.

Here community composition refers to the assemblage of species found to occur within a treatment category as determined by species relative abundance. It was not always the case that the species shown in the SIMPER results were found to exhibit corresponding significant differences during ANOVA analyses, which independently considered the abundance of each species. This was due in part to the ANOSIM subtleties mentioned below.

For any given species, both its relative abundance and pattern of distribution can affect the ANOSIM results. For example, a species may have similar relative abundance values between treatments and yet may still contribute considerably to the overall dissimilarity between treatments because of differences in its pattern of distribution. In one treatment the species may be evenly distributed, causing it to have persistent yet comparatively low relative abundance estimates throughout the sampled area, while in another treatment, the same species may have a clumped distribution where it is mostly absent from sampled areas, except in the few areas where it is very abundant. Both scenarios can result in similar overall relative abundance estimates but can also result in the species being found to contribute considerably to the level of dissimilarity between treatments.

Table 7. SIMPER results for spring forest Partial v. Total comparison, showing the cumulative eightieth percentile of observed differences contributed by individual species between treatments over all years. Column headings: Species/Taxa Abbrev - species/taxonomic group abbreviation (these abbreviations can be cross-referenced with the actual species or taxonomic group using tables 5 or 6), Partial Avg RA – Partial Average Relative Abundance, Total Avg RA – Total Average Relative Abundance, Avg Diss – Average Dissimilarity, Avg Diss/SD – Average Dissimilarity / the standard deviation of all pairs of samples making up the Average Dissimilarity, % Contribution – Percent contribution of observed dissimilarity for a given species or taxonomic group, Cumulative % - The cumulative percent contribution of dissimilarity by all species shown from top to bottom.

Spring Forest SIMPER Results						
Species/Taxa Abbrev	Partial Avg RA	Total Avg RA	Avg Diss	Avg Diss/SD	% Contribution	Cumulative %
SMRO	0.24	0.33	18.44	1.11	24.0	24.0
PITA	0.19	0.17	13.9	0.83	18.1	42.1
CHLA	0.19	0.16	13.1	0.91	17.0	59.1
TORA	0.06	0.08	5.93	0.61	7.7	66.8
VIRO	0.04	0.07	5.33	0.45	6.9	73.8
VACO	0.06	0.03	4.06	0.44	5.3	79.0
MOSP	0.05	0.02	3.26	0.42	4.2	83.3

During the spring in forest study sites there was a significant difference between vegetative communities when all years were pooled (n=48) for each treatment (Global R = .001, p = .004). Protected pair-wise comparisons revealed a significant difference between Partial and Total treatments (R Statistic = .021, p = .002). Table 7 shows the results of SIMPER analysis for these data. These results indicate that the community composition of Partial treatment areas was significantly different from that of Total treatment areas. According to these analyses *Smilax rotundifolia*, *Pinus taeda* and *Chasmanthium laxum* contributed nearly 60% of the dissimilarity between these treatments.

Here *S. rotundifolia*, which is heavily browsed by deer, was considerably more abundant in Total treatment areas while *P. taeda* and *C. laxum* were only marginally more abundant in Partial treatment areas. The fact that a similar result was not found for the Control-Total comparison (p=0.085) is somewhat surprising. Deer apparently do not graze heavily on *C. laxum*, therefore its marginally higher relative abundance in Partial, as compared to Total treatment areas is consistent with other findings during this research (see *C. laxum* absolute abundance analysis results).

The *P. taeda* findings from this and other SIMPER analyses are likely the result of its pattern of distribution in forested treatment areas. Most contacts by this species were the result of the sampling pin passing through or directly alongside a *P. taeda* tree trunk (i.e. numerous contacts occurred in some treatment areas via the fortuitous placement of one or more sampling pins while the same sampling intensity yielded few *P. taeda* contacts in other treatment areas). *P. taeda*, which is the dominant tree species in forest study sites, was the only species whose spatial distribution within sampled areas posed this kind of a detection problem. As a result, the finding that *P. taeda* contributed to the level of dissimilarity between treatments should be met with some skepticism. No evidence of preferential browsing on this species was found nor was the time frame of this project sufficient to allow *P. taeda*, which is a long lived tree species, time to respond to project treatments.

Table 8. SIMPER results for Control v. Partial comparison, showing the cumulative eightieth percentile of observed differences contributed by individual species between treatments over all years. See Table 7 for a description of column headings.

Summer Forest SIMPER Results						
Species/Taxa Abbrev	Control Avg RA	Partial Avg RA	Avg Diss	Avg Diss/SD	% Contribution	Cumulative %
CHLA	0.24	0.3	17.04	1.15	22.3	22.3
SMRO	0.23	0.21	15.28	0.96	20.0	42.3
PITA	0.21	0.15	14.23	0.83	18.6	61.0
MOSP	0.08	0.05	5.95	0.51	7.8	68.8
VACO	0.02	0.05	3.21	0.35	4.2	73.0
TORA	0.04	0.02	2.75	0.4	3.6	76.6
PAVI	0.03	0.03	2.56	0.43	3.4	79.9
VIRO	0.03	0.03	2.51	0.36	3.3	83.2

Table 9. SIMPER results for summer forest Control v. Total comparison, showing the cumulative eightieth percentile of observed differences contributed by individual species between treatments over all years. See Table 7 for a description of column headings.

Summer Forest SIMPER Results						
Species/Taxa Abbrev	Control Avg RA	Total Avg RA	Avg Diss	Avg Diss/SD	% Contribution	Cumulative %
CHLA	0.24	0.32	17.45	1.18	23.5	23.5
SMRO	0.23	0.23	14.85	1.05	20.0	43.5
PITA	0.21	0.15	13.96	0.85	18.8	62.2
MOSP	0.08	0.02	4.65	0.44	6.3	68.5
TORA	0.04	0.06	4.4	0.48	5.9	74.4
VIRO	0.03	0.05	3.44	0.5	4.6	79.1
PAVI	0.03	0.03	2.51	0.34	3.4	82.4

Table 10. SIMPER results for summer forest Partial v. Total comparison, showing the cumulative eightieth percentile of observed differences contributed by individual species between treatments over all years. See Table 7 for a description of column headings. Please note the pair-wise comparison of these two treatments during this round of data was not significant and these results are included for comparison only.

Summer Forest SIMPER Results						
Species/Taxa Abbrev	Partial Avg RA	Total Avg RA	Avg Diss	Avg Diss/SD	% Contribution	Cumulative %
CHLA	0.3	0.32	16.82	1.24	23.4	23.4
SMRO	0.21	0.23	13.91	1.07	19.3	42.7
PITA	0.15	0.15	11.91	0.8	16.6	59.3
VIRO	0.03	0.05	3.58	0.43	5.0	64.2
TORA	0.02	0.06	3.56	0.48	4.9	69.2
VACO	0.05	0.02	3.28	0.37	4.6	73.7
MOSP	0.05	0.02	3.28	0.4	4.6	78.3
PAVI	0.03	0.03	2.6	0.42	3.6	81.9

Significant differences in vegetation communities were also found during the summer in forest study sites when all years were pooled for each treatment (ANOSIM, Global R = .016, p = .0008). Protected pair-wise comparisons revealed a significant difference between Control and Partial treatments (R Statistic = .015, p = .010) and Control and Total treatments (R Statistic = .023, p = .002). Tables 8 and 9 show the results of the SIMPER analyses for the significant comparison mentioned above. It is important to note that the pair-wise comparison between the Partial and Total treatments for this round of data was nearly significant (R Statistic = .01, p = .030), however this result does not satisfy the protected procedure requirement of $p < .0167$. Though not significant, the SIMPER analysis results for the Summer-Forest Partial v. Total treatments has been included solely for comparison, see Table 10.

SIMPER analyses conducted after significant ANOSIM results from the Summer-Forest data revealed similar conclusions. Here *C. laxum*, *S. rotundifolia*, and *P. taeda* contributed approximately 60% of the dissimilarity between both Control-Partial and Control-Total pair-wise comparisons. *C. laxum* was the largest contributor to dissimilarity during each of these pair-wise comparisons. This is consistent with the ANOVA analyses results from this round during which this grass was found to be significantly less abundant in Control treatment areas (see Table 14). Additionally, both of the SIMPER analyses mentioned above, Tables 8 and 9, revealed a comparable *S. rotundifolia* relative abundance between treatments. This result likely came from the tendency of *S. rotundifolia* to be more evenly distributed in Total and Partial treatment areas while exhibiting a more clumped distribution pattern in Control treatment areas. That is to say, upon exposure to varying degrees of rest from grazing (i.e. Total and Partial treatments) *S. rotundifolia* begins to occupy new areas, other than those where it had already managed to become abundant prior to being exposed to project treatments (i.e. over a shrub or up a tree). Of further interest is that *Vitis rotundifolia*, which also contributed to the level of dissimilarity between sites, had lower relative abundances in treatment areas that were exposed to ungulate herbivory (i.e. Control and Partial treatments). This result is also consistent with ANOVA findings presented in Table 14.

Table 11. SIMPER results for summer shrub Control v. Total comparison, showing the cumulative eightieth percentile of observed differences contributed by individual species between treatments over all years. See Table 7 for a description of column headings.

Summer Shrub SIMPER Results						
Species/Taxa Abbrev	Control Avg RA	Total Avg RA	Avg Diss	Avg Diss/SD	% Contribution	Cumulative %
SPPA	0.24	0.25	14.13	1.22	18.0	18.0
ANVI	0.09	0.07	6.3	0.8	8.0	26.0
SCSC	0.07	0.06	5.57	0.59	7.1	33.1
HUTO	0.06	0.06	5.3	0.62	6.7	39.8
MOSP	0.07	0.07	4.79	0.93	6.1	45.9
AMBR	0.04	0.08	4.62	0.71	5.9	51.8
SCPU	0.07	0.03	4.13	0.73	5.3	57.0
ARTU	0.04	0.02	2.92	0.45	3.7	60.7
JUDI	0.03	0.03	2.5	0.77	3.2	63.9
PAVI	0.03	0.02	2.07	0.68	2.6	66.5
DIAC	0.03	0.02	1.92	0.62	2.4	69.0
DISP	0.02	0.02	1.76	0.57	2.2	71.2
VACO	0.01	0.02	1.54	0.42	2.0	73.2
FICA	0.01	0.02	1.33	0.4	1.7	74.9
JUSC	0.02	0.01	1.31	0.46	1.7	76.5
PITA	0.02	0.01	1.26	0.27	1.6	78.1
TORA	0.01	0.02	1.17	0.62	1.5	79.6
PAAM	0.01	0.01	1.17	0.58	1.5	81.1

ANOSIM found a significant difference in the vegetation communities during the summer in shrub study sites when all years were pooled for each treatment (Global R = .012, p = .007). Protected pair-wise comparisons revealed a significant difference between Total v. Control treatments (R Statistic = .016, p = .013). Furthermore it is important to note that the pair-wise comparison between Total v. Partial (Global R = .009, p = .048) and Partial v. Control (Global R = .011, p = .035) treatments for this round were nearly significant, however once again these results do not satisfy the protected procedure requirements ($p < .0167$). Table 11 shows the SIMPER analyses for the significant result mentioned above. In addition, though not significant, SIMPER analysis results for the Summer-Shrub Total v. Partial and Partial v. Control treatments are presented in Tables 12 and 13.

The Summer-Shrub SIMPER analyses results shown in Table 11 indicate that the community composition of Control treatment areas was significantly different from that of Total treatment areas. According to these analyses *Spartina patens*, *Andropogon virginicus*, *Schizachyrium scoparium*, *Hudsonia tomentosa*, *Morella* spp., *Ammophila breviligulata*, *Schoenoplectus pungens* and *Aristida tuberculosa* together contributed roughly 60% of the dissimilarity between treatments. *S. patens*, *H. tomentosa*, and *Morella* spp. all exhibited similar relative abundances between Control and Total treatment areas during these analyses therefore their patterns of distribution must contribute considerably to the dissimilarity between treatments. The distribution of each of these species did not vary considerably within each treatment during this research and therefore this finding is likely the result of variations in the distribution of each of these species prior to project commencement.

Table 12. SIMPER results for summer shrub Partial v. Total comparison, showing the cumulative eightieth percentile of observed differences contributed by individual species between treatments over all years. See Table 7 for a description of column headings. Please note the pair-wise comparison of the two treatments during this round of data was not significant and these results are included for comparisons sake only.

Summer Shrub SIMPER Results						
Species/Taxa Abbrev	Partial Avg RA	Total Avg RA	Avg Diss	Avg Diss/SD	% Contribution	Cumulative %
SPPA	0.26	0.25	14.99	1.21	19.1	19.1
AMBR	0.08	0.08	5.86	0.81	7.5	26.5
HUTO	0.06	0.06	5.16	0.63	6.6	33.1
MOSP	0.07	0.07	4.96	0.87	6.3	39.4
ANVI	0.05	0.07	4.9	0.73	6.2	45.6
SCSC	0.02	0.06	3.52	0.52	4.5	50.1
SCPU	0.06	0.03	3.5	0.69	4.5	54.5
JUDI	0.04	0.03	2.97	0.69	3.8	58.3
ARTU	0.04	0.02	2.68	0.5	3.4	61.7
PAVI	0.03	0.02	2.22	0.64	2.8	64.6
EUHY	0.03	0.02	2.11	0.37	2.7	67.2
FICA	0.02	0.02	1.89	0.48	2.4	69.6
DISP	0.02	0.02	1.87	0.55	2.4	72.0
DIAC	0.03	0.02	1.74	0.72	2.2	74.2
TORA	0.01	0.02	1.32	0.64	1.7	75.9
LEMA	0.01	0.02	1.29	0.34	1.7	77.5
JUSC	0.02	0.01	1.29	0.51	1.6	79.2
VACO	0.01	0.02	1.21	0.36	1.5	80.7

It is interesting to note that *A.virginicus* and *S. scoparium* were most abundant in Control treatment areas. Both are important perennial bunch grasses that evolved under the influence of large ungulate grazing pressures in the short and tall grass prairie regions of North America. These results indicate that the abundance of these species on Assateague Island may largely be influenced by horse herbivory. However, although it is interesting to speculate, these results remain inconclusive and further research would be required to verify this hypothesis.

In addition to the two previously mentioned species *A. tuberculosa* and *S. pungens* exhibited a similar result, being most abundant under high grazing pressure. The

ANOVA analyses of *S. pungens* abundance reconfirmed this result, (see Table 15) revealing that this species was significantly more abundant in Control treatment areas.

A. breviligulata revealed an opposite result. Its abundance was highest in Total treatment areas. Once again this result was reconfirmed during the ANOVA analyses (see Table 15) and in addition was consistent with the findings of previous research (Saliskar 1997, DeStoppelaire 2002) which documented that horse grazing reduced *A. breviligulata* abundance on Assateague Island.

Tables 12 and 13 show SIMPER results from pair-wise comparisons between the Partial and Total treatments and the Partial and Control treatments. Though not found to be significant (they were only nearly so at α_e =0.05) these results are largely consistent with the results found in Table 11. It is interesting to note that during this round, those species found to be contributing to heterogeneity between Partial treatment areas and other treatments were the same as those found to be contributing to heterogeneity between the Control and Total treatments, although not necessarily in the same order.

Table 13. SIMPER results for summer shrub Control v. Partial comparison, showing the cumulative eightieth percentile of observed differences contributed by individual species between treatments over all years. See Table 7 for a description of column headings. Please note the pair-wise comparison of the two treatments during this round of data was not significant and these results are included for comparisons sake only.

Summer Shrub SIMPER Results						
Species/Taxa Abbrev	Control Avg RA	Partial Avg RA	Avg Diss	Avg Diss/SD	% Contribution	Cumulative %
SPPA	0.24	0.26	14.85	1.2	19.0	19.0
ANVI	0.09	0.05	5.79	0.77	7.4	26.4
HUTO	0.06	0.06	5.11	0.66	6.5	33.0
MOSP	0.07	0.07	4.9	0.88	6.3	39.2
SCPU	0.07	0.06	4.83	0.83	6.2	45.4
AMBR	0.04	0.08	4.66	0.77	6.0	51.4
SCSC	0.07	0.02	4.2	0.48	5.4	56.8
ARTU	0.04	0.04	3.34	0.5	4.3	61.0
JUDI	0.03	0.04	2.76	0.7	3.5	64.6
PAVI	0.03	0.03	2.64	0.71	3.4	68.0
DIAC	0.03	0.03	2.2	0.69	2.8	70.8
EUHY	0.01	0.03	1.73	0.31	2.2	73.0
DISP	0.02	0.02	1.7	0.52	2.2	75.2
JUSC	0.02	0.02	1.52	0.51	2.0	77.1
FICA	0.01	0.02	1.38	0.39	1.8	78.9
PHAU	0.01	0.01	1.21	0.53	1.6	80.4

Species Absolute Abundance ANOVA and Tukey Results and Discussion

Tables 14 through 16 present significant ANOVA and Tukey test results from the analyses of the absolute abundance (AA) estimates. Data from each sampling round were analyzed separately as were data from forest and shrub habitats. Protected post-hoc analyses were conducted in accordance with the results of the initial experiment-wise ANOVA analyses. Taxa abbreviations found in Tables 14 to 16 can be cross-referenced with the actual species or taxonomic groups using Tables 5 or 6.

Table 14. ANOVA and Tukey* test results for treatment comparisons of absolute abundance (AA) at forest study sites over all years (2003-2005). For each sampling round, study site, taxa and treatment category the table presents the mean, standard error and sample size (n). The final column indicates whether the results appear to be primarily driven by horse or deer herbivory.

Forest Absolute Abundance 2003 - 2005										
Sampling Round	Study Site(s)	Taxa	Treatment	AA Mean	AA Standard Error	n	Posthoc ANOVA p-value	Tukey Test Results Pairwise Comparison Probability		Horse or Deer ?
Spring	All Combined	ACRU Sapling	Total	0.025	0.009	144	0.010	Total - Partial	0.009	Deer
			Partial	0.003	0.002	144		Total - Control	0.065	
			Control	0.008	0.003	144		Partial - Control	0.766	
		CASP	Total	0.010	0.003	144	0.014	Total - Partial	0.049	Deer
			Partial	0.003	0.002	144		Total - Control	0.018	
			Control	0.002	0.001	144		Partial - Control	0.930	
	F27N	TORA	Total	0.102	0.027	36	0.001	Total - Partial	0.001	Deer
			Partial	0.002	0.002	36		Total - Control	0.035	
			Control	0.037	0.016	36		Partial - Control	0.371	
		VIRO	Total	0.155	0.042	36	0.003	Total - Partial	0.005	Deer
			Partial	0.032	0.016	36		Total - Control	0.018	
			Control	0.049	0.015	36		Partial - Control	0.907	
	F27S	ACRU Sapling	Total	0.097	0.032	36	0.000	Total - Partial	0.002	Deer
			Partial	0.005	0.003	36		Total - Control	0.001	
			Control	0.000	0.000	36		Partial - Control	0.983	
	FGRN	CHLA	Total	0.384	0.091	36	0.002	Total - Partial	0.292	Horse
			Partial	0.255	0.048	36		Total - Control	0.001	
			Control	0.072	0.022	36		Partial - Control	0.090	
Summer	All Combined	ACRU Sapling	Total	0.027	0.009	144	0.001	Total - Partial	0.004	Deer
			Partial	0.002	0.001	144		Total - Control	0.006	
			Control	0.003	0.002	144		Partial - Control	0.987	
		CHLA	Total	0.567	0.068	144	0.009	Total - Partial	0.987	Horse
			Partial	0.553	0.069	144		Total - Control	0.016	
			Control	0.323	0.047	144		Partial - Control	0.025	
		ILOP	Total	0.000	0.000	144	0.009	Total - Partial	1.000	Horse
			Partial	0.000	0.000	144		Total - Control	0.021	
			Control	0.009	0.004	144		Partial - Control	0.021	
		VIRO	Total	0.062	0.015	144	0.003	Total - Partial	0.003	Deer
			Partial	0.016	0.006	144		Total - Control	0.044	
			Control	0.028	0.007	144		Partial - Control	0.635	
	F27S	ACRU Sapling	Total	0.106	0.033	36	0.000	Total - Partial	0.001	Deer
			Partial	0.005	0.003	36		Total - Control	0.000	
			Control	0.000	0.000	36		Partial - Control	0.984	
		SMRO	Total	0.201	0.037	36	0.000	Total - Partial	0.000	Deer
			Partial	0.056	0.010	36		Total - Control	0.006	
			Control	0.090	0.020	36		Partial - Control	0.587	
	FGRN	CHLA	Total	0.877	0.118	36	0.002	Total - Partial	0.761	Horse
			Partial	0.845	0.174	36		Total - Control	0.003	
			Control	0.683	0.145	36		Partial - Control	0.021	

* see page 16 for an explanation of Tukey test results.

Table 15. ANOVA and Tukey* test results for treatment comparisons of absolute abundance (AA) at shrub study sites over all years (2003-2005). For each sampling round, study site, taxa and treatment category the table presents the mean, standard error and sample size (n). The final column indicates whether the results appear to be primarily driven by horse or deer herbivory.

Shrub Absolute Abundance 2003 - 2005										
Sampling Round	Study Site(s)	Taxa	Treatment	AA Mean	AA Standard Error	n	Posthoc ANOVA p-value	Tukey Test Results Pairwise Comparison	Probability	Horse or Deer ?
Spring	All Combined	CIHO	Total	0.008	0.003	144	0.005	Total - Partial	0.017	Deer
			Partial	0.001	0.001	144		Total - Control	0.009	
			Control	0.000	0.000	144		Partial - Control	0.976	
		EUHY	Total	0.035	0.007	144	0.001	Total - Partial	0.001	Deer
			Partial	0.009	0.004	144		Total - Control	0.005	
			Control	0.012	0.003	144		Partial - Control	0.925	
		RUSP	Total	0.152	0.033	144	0.000	Total - Partial	0.000	Deer
			Partial	0.014	0.004	144		Total - Control	0.000	
			Control	0.015	0.006	144		Partial - Control	0.999	
		SOSE	Total	0.048	0.009	144	0.000	Total - Partial	0.000	Deer
			Partial	0.014	0.004	144		Total - Control	0.000	
			Control	0.014	0.004	144		Partial - Control	0.998	
	SH34	AMBR	Total	0.546	0.069	36	0.005	Total - Partial	0.607	Horse
			Partial	0.648	0.094	36		Total - Control	0.057	
			Control	0.299	0.058	36		Partial - Control	0.004	
		ANVI	Total	0.201	0.055	36	0.000	Total - Partial	0.063	Horse
			Partial	0.037	0.020	36		Total - Control	0.017	
			Control	0.403	0.066	36		Partial - Control	0.000	
		RUSP	Total	0.516	0.107	36	0.000	Total - Partial	0.000	Deer
			Partial	0.025	0.010	36		Total - Control	0.000	
			Control	0.000	0.000	36		Partial - Control	0.955	
	SH31	EUHY	Total	0.065	0.022	36	0.011	Total - Partial	0.040	Deer
			Partial	0.014	0.012	36		Total - Control	0.016	
			Control	0.007	0.005	36		Partial - Control	0.940	
		TORA	Total	0.727	0.156	36	0.001	Total - Partial	0.001	Deer
			Partial	0.164	0.054	36		Total - Control	0.017	
			Control	0.322	0.068	36		Partial - Control	0.527	
		VIRO	Total	0.181	0.087	36	0.007	Total - Partial	0.011	Deer
			Partial	0.000	0.000	36		Total - Control	0.026	
			Control	0.009	0.009	36		Partial - Control	0.946	
	SH20	PHAU	Total	0.084	0.028	36	0.018**	Total - Partial	0.109	Deer
			Partial	0.194	0.046	36		Total - Control	0.016	
			Control	0.236	0.039	36		Partial - Control	0.723	
		SCPU	Total	0.055	0.017	36	0.000	Total - Partial	0.093	Horse (and Deer?)
			Partial	0.218	0.062	36		Total - Control	0.000	
			Control	0.412	0.070	36		Partial - Control	0.035	
		TORA	Total	0.007	0.005	36	0.001	Total - Partial	0.993	Horse
			Partial	0.012	0.009	36		Total - Control	0.003	
			Control	0.134	0.046	36		Partial - Control	0.005	

* see page 16 for an explanation of Tukey test results.

** This result is not significant under the protected procedures used during these analyses. (0.018 < 0.0167) and has been presented here strictly for information purposes.

Table 15 continued.

Shrub Absolute Abundance 2003 - 2005										
Sampling Round	Study Site(s)	Taxa	Treatment	AA Mean	AA Standard Error	n	Posthoc ANOVA p-value	Tukey Test Results Pairwise Comparison Probability		Horse or Deer ?
Summer	All Combined	AMBR	Total	0.186	0.026	144	0.003	Total - Partial	0.995	Horse
			Partial	0.189	0.025	144		Total - Control	0.008	
			Control	0.092	0.015	144		Partial - Control	0.006	
		CIVU	Total	0.006	0.003	144	0.010	Total - Partial	0.023	Deer
			Partial	0.000	0.000	144		Total - Control	0.024	
			Control	0.000	0.000	144		Partial - Control	1.000	
		FICA	Total	0.124	0.027	144	0.014	Total - Partial	0.884	Horse
			Partial	0.142	0.036	144		Total - Control	0.058	
			Control	0.037	0.011	144		Partial - Control	0.016	
		LEMA	Total	0.072	0.019	144	0.000	Total - Partial	0.001	Deer
			Partial	0.016	0.006	144		Total - Control	0.000	
			Control	0.003	0.002	144		Partial - Control	0.736	
		RUSP	Total	0.042	0.008	144	0.000	Total - Partial	0.000	Deer
			Partial	0.010	0.003	144		Total - Control	0.000	
			Control	0.008	0.004	144		Partial - Control	0.971	
		SCPU	Total	0.148	0.032	144	0.000	Total - Partial	0.018	Deer
			Partial	0.334	0.052	144		Total - Control	0.000	
			Control	0.431	0.058	144		Partial - Control	0.332	
		VIRO	Total	0.019	0.007	144	0.005	Total - Partial	0.013	Deer
			Partial	0.002	0.002	144		Total - Control	0.013	
			Control	0.002	0.001	144		Partial - Control	1.000	
	SH34	AMBR	Total	0.539	0.060	36	0.000	Total - Partial	0.441	Horse
			Partial	0.444	0.062	36		Total - Control	0.000	
			Control	0.208	0.039	36		Partial - Control	0.008	
		RUSP	Total	0.116	0.022	36	0.000	Total - Partial	0.000	Deer
			Partial	0.012	0.007	36		Total - Control	0.000	
			Control	0.000	0.000	36		Partial - Control	0.810	
	SH31	TORA	Total	0.183	0.050	36	0.002	Total - Partial	0.004	Deer
			Partial	0.039	0.013	36		Total - Control	0.011	
			Control	0.053	0.016	36		Partial - Control	0.947	
		VIRO	Total	0.065	0.012	36	0.003	Total - Partial	0.003	Deer
			Partial	0.000	0.000	36		Total - Control	0.044	
			Control	0.007	0.005	36		Partial - Control	0.635	
		EUHY	Total	0.083	0.021	36	0.000	Total - Partial	0.000	Deer
			Partial	0.007	0.005	36		Total - Control	0.000	
			Control	0.005	0.003	36		Partial - Control	0.991	
		LEMA	Total	0.213	0.064	36	0.001	Total - Partial	0.010	Deer
			Partial	0.049	0.020	36		Total - Control	0.001	
			Control	0.009	0.006	36		Partial - Control	0.755	
		PAAM	Total	0.111	0.031	36	0.009	Total - Partial	0.034	Deer
			Partial	0.037	0.014	36		Total - Control	0.015	
			Control	0.028	0.011	36		Partial - Control	0.946	
	SH20	FICA	Total	0.447	0.089	36	0.010	Total - Partial	0.925	Horse
			Partial	0.488	0.126	36		Total - Control	0.035	
			Control	0.118	0.041	36		Partial - Control	0.015	
		SCPU	Total	0.157	0.030	36	0.000	Total - Partial	0.009	Deer (and Horse?
			Partial	0.532	0.112	36		Total - Control	0.000	
			Control	0.794	0.098	36		Partial - Control	0.093	
	SHNG	LEMA	Total	0.030	0.012	36	0.005	Total - Partial	0.009	Deer
			Partial	0.000	0.000	36		Total - Control	0.018	
			Control	0.002	0.002	36		Partial - Control	0.971	

* see page 16 for an explanation of Tukey test results.

Table 16. ANOVA and Tukey* test results for treatment x year comparisons of absolute abundance (AA) at shrub study sites. For each sampling round, study site, taxa and treatment-year category the table presents the mean, standard error and sample size (n). The final column indicates whether the results appear to be primarily driven by horse or deer herbivory.

Shrub Absolute Abundance 2003 - 2005										
Sampling Round	Study Site(s)	Taxa	Treatment-Year	AA Mean	AA Standard Error	n	Posthoc ANOVA p-value	Tukey Test Results Pairwise Comparison Probability		Horse or Deer ?
Spring	All Combined	AGST	Control-03	0.030	0.009	48	0.000	Control 03 - 04	0.000	Deer (and Horse?
			Control-04	0.000	0.000	48		Control 03 - 05	0.001	
			Control-05	0.002	0.002	48		Control 04 - 05	0.973	
		AGST	Partial-03	0.023	0.007	48	0.000	Partial 03 - 04	0.000	Deer
			Partial-04	0.000	0.000	48		Partial 03 - 05	0.000	
			Partial-05	0.000	0.000	48		Partial 04 - 05	1.000	
		EUTE	Total-03	0.000	0.000	48	0.009	Total 03 - 04	1.000	Deer
			Total-04	0.000	0.000	48		Total 03 - 05	0.019	
			Total-05	0.036	0.017	48		Total 04 - 05	0.019	

* see page 16 for an explanation of Tukey test results.

Acer rubrum - saplings

In forest habitats during the spring and summer *Acer rubrum* saplings exhibited significantly higher overall absolute abundances values in Total treatment areas as compared to both Partial and Control treatment areas. A similar result was found for *A. rubrum* saplings during both spring and summer at study site F27S. According to these results, current levels of deer herbivory are reducing the abundance of *A. rubrum* saplings and thus negatively impacting the reproductive success of this species. Over the past century this has conceivably altered the composition of dominant tree species in Assateague Island's maritime forest habitats, which are currently dominated by *P. taeda*.

In the closed canopy forest habitats on the Maryland end of Assateague Island *A. rubrum* typically occurs as a sub-dominant component of the understory and only occasionally achieves dominant status in infrequent, localized areas. In the absence of other influencing factors that may also be limiting *A. rubrum* abundance, exposure to salt spray or overwash for example, a decrease in the level of deer herbivory would likely result in an increase in the reproductive success of *A. rubrum,* which in time may allow this species to establish itself as a co-dominant tree species on Assateague Island. Given these results *A. rubrum* saplings are worthy of consideration for inclusion in the planned long-term monitoring program.

Agrostis stolonifera

In shrub habitats during the spring *Agrostis stolonifera* had significantly higher absolute abundance in Control treatment areas during 2003 as compared to Control treatment areas during both 2004 and 2005. A similar result was found in Partial treatment areas during 2003 as compared to Partial treatment areas during both 2004 and 2005. These results indicate that *A. stolonifera* decreased in shrub habitats within grazed treatment areas throughout the duration of this project. On Assateague Island, *A. stolonifera* is a naturalized, exotic grass species whose abundance ranges from infrequent to locally frequent. Of equal importance to these significant results is the fact that *A. stolonifera* did not increase in abundance within Total treatment areas, upon exposure to rest from deer and horse herbivory. Therefore, although *A. stolonifera* demonstrated lower abundance at grazed sites during this research, it should not be considered for inclusion as part of the planned long-term monitoring program without first better understanding its possible response to reductions in grazing pressure.

Ammophila breviligulata

In shrub habitats during the summer *Ammophila breviligulata* had significantly lower overall absolute abundance in Control treatment areas as compared to both Partial and Total treatment areas. Similar results were found during both spring and summer at the SH34 study site. This response indicates that *A. breviligulata* is sensitive to horse herbivory and exposure to rest from horse herbivory allows the species to increase in abundance. *A. breviligata* is widespread and frequent on Assateague Island. These findings reconfirm prior research at Assateague (Seliskar 1997, DeStoppelaire 2002) that also found that *A. breviligulata* was sensitive to horse grazing. This sensitivity to horse herbivory makes *A. breviligulata* an excellent candidate species, worthy of consideration as part of a long term monitoring program.

Carex spp.

In forest habitats during the spring the overall absolute abundance of *Carex* spp. was significantly higher in Total treatment areas as compared to both Partial and Control treatment areas. This result indicates that deer herbivory is largely responsible for reducing *Carex* spp. abundance in forest habitats. Although this result makes *Carex* spp. worthy of consideration for inclusion as part of any future adaptive monitoring program, it is important to point out that the various *Carex* species found on Assateague Island frequently have similar taxonomic characteristics at certain times during the growing season, frequently making it difficult to distinguish between species. Many *Carex* species were included in this taxonomic group (see page 26) and still others would conceivably be included should *Carex* spp. be incorporated as part of a monitoring program. These issues should be further resolved prior to the inclusion of *Carex* spp. as part of such a program.

Chasmanthium laxum

In forest habitats during the summer *Chasmanthium laxum* had significantly lower absolute abundance in Control treatment areas as compared to both Partial and Total treatment areas over all study sites combined. Similar results were found during both spring and summer at the FGRN forest study site. These results consistently indicate that rest from horse herbivory increased the abundance of *C. laxum* in forested habitats. As a result *C. laxum* should be considered for inclusion as part of the planned long-term monitoring program.

Cirsium horridulum and *C. vulgare*

Cirsium horridulum had significantly higher absolute abundances in Total treatment areas as compared to both Partial and Control treatment areas in shrub habitats during the spring while *C. vulgare* exhibited a similar result in shrub habitats during summer. These results indicate that rest from deer herbivory increased the abundance of both *C. horridulum* and *C. vulgare* in shrub habitats. *C. horridulum* is a native biennual thistle that blooms from May to June that is considered rare by the Maryland Natural Heritage Program. *C. vulgare* is an introduced, exotic biennial thistle from Eurasia that blooms from July to September and that by now has become naturalized in North America. Both species are widely distributed yet infrequent on Assateague Island. Given their apparent sensitivity to deer herbivory, both species appear to have excellent potential for incorporation into a long-term vegetation monitoring program.

Eupatorium hyssopifolium

In shrub habitats during the spring *Eupatorium hyssopifolium* had significantly higher overall absolute abundance in Total treatment areas as compared to both Partial and Control treatment areas. Similar results were found during both spring and summer at the SH31 study site. *E. hyssopifolium* is a native biennial or perennial composite species that ranges from infrequent to locally frequent on Assateague Island. Its response to project treatments indicate that it increases in abundance in response to a reduction in the intensity of deer herbivory. This sensitivity to deer herbivory makes *E. hyssopifolium* an excellent candidate species, worthy of consideration as part of a planned long-term monitoring program.

Euphorbia tenuifolia

In shrub habitats during the spring *Euphorbia tenuifolia* had significantly higher absolute abundance in Total treatment areas during 2005 as compared to Control treatment areas during both 2003 and 2004. This result indicates that by the third growing season after exposure to rest from ungulate grazing (and more specifically deer grazing), *E. tenuifolia* is capable of significantly increasing in abundance. This result makes *E. tenuifolia* worthy of consideration for inclusion in the planned long-term monitoring program.

Fimbristylis castanea

In shrub habitats during the summer *Fimbristylis castanea* had significantly lower overall absolute abundance in Control treatment areas as compared to both Partial and Total treatment areas. A similar result was found during summer sampling at the SH20 study site. These results indicate that horse herbivory reduces the abundance of *F. castanea*, a perennial herbaceous species that is most abundant in the transition zone between high and low salt marsh communities. *F. castanea* should be considered as a candidate species worthy of inclusion in the long-term monitoring program, however given its observed propensity to fluctuate widely in abundance in areas where it occurs, further research designed to reconfirm this result is also recommended.

Ilex opaca

In forest habitats during the summer *Ilex opaca* had significantly higher overall absolute abundance in Control treatment areas as compared to both Partial and Total treatment areas. *I. opaca* is a shade tolerant, understory tree species that occasionally occurs in Assateague's maritime forest habitats. During this project *I. opaca* only occurred in the F27N Control, FGRN Control and FGRN Partial treatment areas. During all six rounds of pin-sampling *I. opaca* was contacted a total of 42 times (38 times in Control treatment and 4 times in Partial treatment areas). The significant ANOVA result for *I. opaca* abundance is likely attributable to the preexisting distribution of this long lived, slow growing tree species within the project's treatment areas and therefore is not the result of any response by this species to treatments during this project. Although, it is possible that deer and horses do have an affect on the abundance of *I. opaca* through browse (0 of 23 *I. opaca* stems were observed to be browsed during this project) and rubbing behavior, it is recommended that despite the significant ANOVA result, the abundance of *I. opaca* not be considered for inclusion as part of a long-term monitoring program without first conducting additional research.

Lechea maritima

In shrub habitats during the summer *Lechea maritima* had significantly higher overall absolute abundance in Total treatment areas as compared to both Partial and Control treatment areas. A similar result was found during summer at the SHNG and SH31 study sites. *L. maritima* is an infrequent, perennial herbaceous species on Assateague Island. Due to its low frequency of occurrence, *L. maritima* has been placed on the "watch list" by the Maryland Department of Natural Resources. During this research *L. maritima* unmistakably, significantly increased in abundance in response to exposure to rest from deer herbivory and as a result should absolutely be included as a component of any program designed to monitor the effects of deer herbivory on Assateague Island.

Panicum amarum

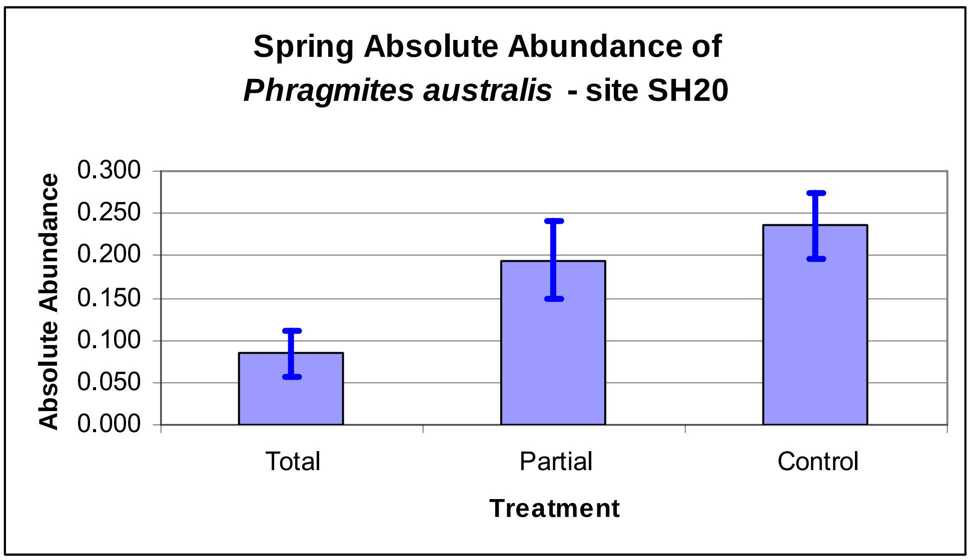
During the summer *Panicum amarum* had significantly higher absolute abundance in the Total treatment area as compared to both Partial and Control treatment areas at the SH31 study site. This result indicates that deer herbivory reduces *P. amarum* abundance during the summer in localized areas on Assateague Island and merits further investigation prior to the inclusion of *P. amarum's* into any long-term monitoring program.

Phragmites australis

The *Phragmites australis* result presented in Table 15 is not significant under the protected procedures used during data analyses (0.018 > 0.0167) and has been presented here strictly for informational purposes. Prior to the commencement of this research, *P. australis* was known to be grazed by all three Assateague Island ungulate species. During data analyses the results for this species were consistently close to being significant across treatments over all sites combined as well as within shrub site SH20 which had the highest abundance of *P. australis*.

Though not significant, the *P. australis* results presented in Table 15 and Figure 14, seem to indicate that exposure to deer herbivory, more than horse herbivory, increases the abundance of *P. australis*. Conceivably, this could be due to a compensatory grazing response by *P. australis*, wherein it increases in abundance via rhizomal expansion upon exposure to herbivory. As an invasive, exotic plant species, such a compensatory response to grazing by both native and exotic ungulates would certainly exacerbate the threats posed by *P. australis* to Assateague Island. Therefore further investigations into the effect of herbivory on the abundance and distribution *P. australis* should be undertaken. However at this time, based on the results of this research *P. australis* should not be considered for inclusion as part of a long-term vegetation monitoring program.

Figure 14. Summer shrub *Phragmites australis* absolute abundance in Total, Partial and Control treatment areas +/- one standard error.



Rubus spp.

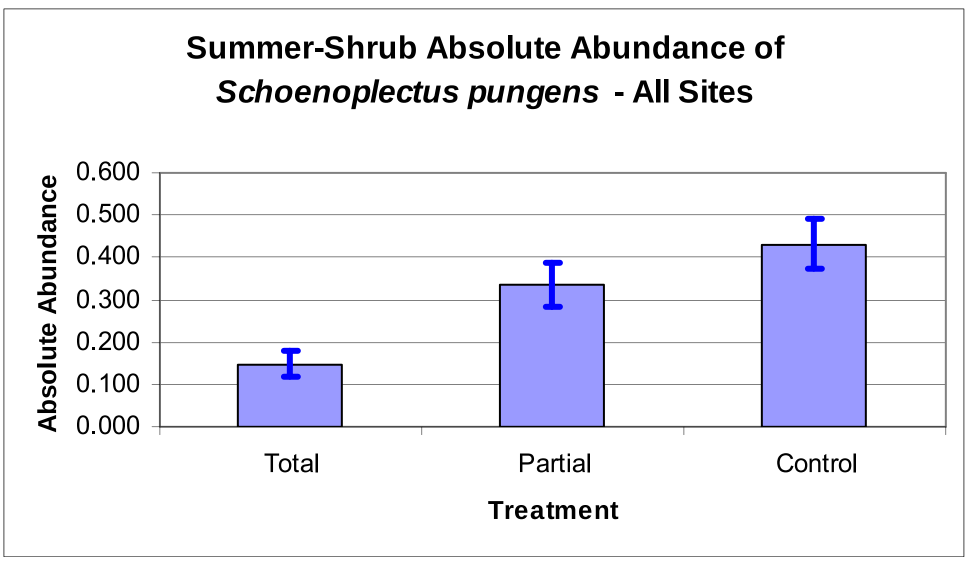
In shrub habitats during both the spring and summer *Rubus* spp. had significantly higher overall absolute abundance in Total treatment areas as compared to both Partial and Control treatment areas. Similar results were found during both spring and summer at the SH34 study site. The *Rubus* spp. response to project treatments illustrates this taxonomic group's sensitivity to deer herbivory and shows that it was able to increase in abundance in response to a reduction in the intensity of deer herbivory. There are three *Rubus* species that are known to occur on Assateague: *R. argutus*, *R.cuneifolius* and *R. flagellaris*. All three species are widespread and locally frequent. The sensitivity of this taxonomic group to deer herbivory make it an excellent candidate, worthy of consideration for inclusion as part of a long-term monitoring program.

Schoenoplectus pungens

In shrub habitats during the summer *Schoenoplectus pungens* (syn: *Scirpus pungens*, *S. americanus*) had significantly lower overall absolute abundance in Total treatment areas as compared to both Partial and Control treatment areas. A similar result was found during summer sampling at the SH20 shrub study site, however during spring sampling at this study site the Control treatment area was found to have a significantly higher *S. pungens* absolute abundance as compared to both Partial and Total treatment areas. These results indicate that during the spring, horse herbivory was found to be significantly increasing the absolute abundance of *S. pungens*, while during the summer deer herbivory had a similar effect. During each round of sampling there was found to be an additive effect caused by increased levels of herbivory by both horses and deer on the abundance of *S. pungens* (Figure 15).

In other words the results indicate that herbivory by either horses or deer increases the abundance of *S. pungens* and furthermore indicate that the combined effect of herbivory by both grazer groups is to further increase *S. pungens* abundance above those levels observed under the influence of just one group.

Figure 15. Summer shrub *Schoenoplectus pungens* absolute abundance in Total, Partial and Control treatment areas +/- one standard error.



The increase in abundance exhibited by *S. pungens* in response to varying levels of ungulate herbivory makes it an excellent candidate species worthy of consideration as part of a long-term monitoring program.

Smilax rotundifolia

In the F27S study site *Smilax rotundifolia* was found to have significantly higher absolute abundance in Total treatment areas as compared to both Partial and Control treatment areas. This result indicates that rest from deer herbivory significantly increased the abundance of *S. rotundifolia* at this site.

S. rotundifolia is a perennial vine that is heavily browsed upon, primarily by deer, (see browse results, Tables 19 and 20). Despite the existing high levels of deer browse that have been present at Assateague Island National Seashore for many decades, *S. rotundifolia* remains an abundant component of Assateague's understory in forested habitats. It reproduces via several means including seed production, rhizomal expansion and adventitious epicormic branching. The fact that *S. rotundifolia* was only found to significantly increase in abundance at one forest study site upon exposure to rest from deer herbivory indicates that any landscape level response by this species to a reduction in the intensity of deer herbivory would likely take place over a time frame that is greater than three years duration of this project. Therefore, any further consideration of the use of *S. rotundifolia* abundance as part of a long-term monitoring program should be preceded by additional investigations aimed at further understanding its apparent delayed response to reductions in the intensity of deer herbivory.

Solidago sempervirens

In shrub habitats during the spring *Solidago sempervirens* had significantly higher overall absolute abundance in Total treatment areas as compared to both Partial and Control treatment areas. Like *E. hyssopifolium* and *E. tenuifolia* above, *S. sempervirens* is a native composite species that increased in abundance in response to lower levels of deer herbivory. *S. sempervirens* is much more abundant and widespread on Assateague Island making it an excellent candidate species, worthy of consideration as part of a long term monitoring program.

Toxicodendron radicans

In forest study site F27N *Toxicodendron radicans* was found to have significantly higher absolute abundance in Total treatment areas as compared to both Partial and Control treatment areas. This is consistent with similar findings for *T. radicans* at shrub study site SH31 from both the spring and summer yet contradicts a significant finding for *T. radicans* during the spring from the SH20 shrub study site in which its abundance in the Control treatment area was significantly higher than those from both the Partial and Total treatment areas.

These contradictory results instill doubt as to the validity of these conclusions. In the case of the F27N result, during this research a tree fell over in the Total treatment area of this study site that was heavily burdened with *T. radicans*, causing a substantial increase in the abundance of *T. radicans*. Regarding the results for this species that were found at the two shrub study sites, there was no obvious single incident that occurred during the implementation of this research that could have caused such contradictory results. Therefore prior to any further consideration towards the use of *T. radicans* as part of a monitoring program, the response by this species to both horse and deer herbivory should first be further investigated.

Vitis rotundifolia

In both forest and shrub habitats during the summer *Vitis rotundifolia* had significantly higher overall absolute abundance in Total treatment areas as compared to Partial and Control treatment areas. Similar results were found during the spring at F27N and SH31 as well as during the summer at the SH31 study site. Each of these significant results indicates that rest from deer herbivory resulted in an increase in *V. rotundifolia* absolute abundance. The consistency of these findings indicates that the abundance of *V. rotundifolia* is heavily influenced by existing levels of deer herbivory in both forest and shrub habitats on Assateague Island. As a result *V. rotundifolia* should be seriously considered for inclusion as part of the planned long-term monitoring program.

Species Height ANOVA and Tukey Results and Discussion

Table 17. ANOVA and Tukey* test results for treatment comparisons of mean height in forest and shrub study sites during both spring and summer over all years. For each sampling round, study site, taxa and treatment category the table presents the height mean, standard error and sample size (n). The final column indicates whether the results appear to be primarily driven by horse or deer herbivory.

Species Height 2003 - 2005										
Sampling Round	Habitat	Taxa	Treatment	Height Mean	Height Standard Error	n	Posthoc ANOVA p-value	Tukey Test Results Pairwise Comparison	Probability	Horse or Deer ?
Spring	Forest	CHLA	Total	15.8	0.4	387	0.000	Total - Partial	0.993	Deer
			Partial	13.7	0.4	277		Total - Control	0.002	
			Control	13.7	0.5	213		Partial - Control	0.001	
		SMRO	Total	54.3	1.4	551	0.000	Total - Partial	0.133	Horse
			Partial	59.6	1.9	358		Total - Control	0.000	
			Control	70.7	1.9	493		Partial - Control	0.023	
	Shrub	MOSP	Total	67.0	1.3	654	0.000	Total - Partial	0.005	Deer
			Partial	74.8	1.6	465		Total - Control	0.000	
			Control	75.4	1.4	634		Partial - Control	0.919	
Summer	Forest	MOSP	Total	83.5	4.8	69	0.000	Total - Partial	0.001	Deer
			Partial	100.5	3.1	112		Total - Control	0.000	
			Control	99.2	2.5	211		Partial - Control	0.960	
		SMRO	Total	53.4	1.7	499	0.000	Total - Partial	0.992	Horse
			Partial	51.5	1.7	405		Total - Control	0.000	
			Control	71.0	1.9	442		Partial - Control	0.000	
	Shrub	DIAC	Total	10.2	1.0	117	0.000	Total - Partial	0.000	Deer
			Partial	15.7	1.2	187		Total - Control	0.000	
			Control	15.2	0.9	232		Partial - Control	0.988	
		LEMA	Total	15.0	0.8	125	0.004	Total - Partial	0.269	?
			Partial	12.0	1.3	27		Total - Control	0.004	
			Control	5.7	1.5	6**		Partial - Control	0.07**	
		SOSE	Total	40.7	3.3	59	0.000	Total - Partial	0.002	Deer
			Partial	20.5	3.6	24		Total - Control	0.009	
			Control	21.7	3.7	21		Partial - Control	0.967	

* see page 16 for an explanation of Tukey test results.

** note the Control treatment's low sample size and the comparatively high probability value for the Partial-Control *Lechea maritima* mean height pair-wise comparison.

Tables 17 and 18 present the significant species height ANOVA and Tukey test results for each species or taxonomic group. Data from each sampling round were analyzed separately as were data from forest and shrub habitats. Protected post-hoc analyses were conducted in accordance with the results of the experiment-wise ANOVA analyses. Taxa abbreviations found in tables 17 to 18 can be cross-referenced with the actual species or taxonomic group using tables 5 or 6

.

Table 18. ANOVA and Tukey* test results for treatment x year comparisons of mean height in shrub study sites. For each sampling round, habitat, taxa and treatment-year category the table presents the HUTO mean height, standard error and sample size (n). The final column indicates whether the results appear to be primarily driven by horse or deer herbivory.

Species Height 2003 - 2005										
Sampling Round	Habitat	Taxa	Treatment-Year	Height Mean	Height Standard Error	n	Posthoc ANOVA p-value	Tukey Test Results Pairwise Comparison Probability		Horse or Deer ?
Summer	Shrub	HUTO	Total 03	7.3	0.3	161	0	2003-2004	0.011	Horse
			Total 04	9.1	0.7	54		2003-2005	0.000	
			Total 05	10.3	0.4	131		2004-2005	0.409	
		HUTO	Partial 03	6.6	0.3	125	0.002	2003-2004	0.005	
			Partial 04	8.5	0.5	56		2003-2005	0.023	
			Partial 05	8.6	0.6	66		2004-2005	0.833	

* see page 16 for an explanation of Tukey test results.

Chasmanthium laxum

In forest habitats during the spring *C. laxum* height was significantly higher in Total treatment areas as compared to Partial and Control treatment areas. This result indicates that the level of deer herbivory experienced by this species during the non-growing season is sufficient to measurably reduce the mean height of *C. laxum* prior to the commencement of the following growing season and reaffirms the value of this species as a worthy candidate for inclusion in a long-term monitoring program. Recall that *C. laxum* abundance was also found to be reduced, primarily by horse herbivory.

Dicanthelium acuminatum

In shrub habitats the summer height of *Dicanthelium acuminatum* was significantly lower in Total treatment areas as compared to both Partial and Control treatment areas. Several varieties of *D. acuminatum* occur on Assateague Island, in addition to several other *Dicanthelium* species that also occur on the island. As a result, although *D. acumina*tum is by far the most common species from this genus found on Assateague, this species group might more accurately be considered as *Dicanthelium* spp. Regardless, the height of *D. acuminatum* was reduced upon exposure to rest from deer grazing. This species group is not preferred forage for deer or horses as evidenced by its not having been observed as grazed during this project.

On Assateague, *D. acuminatum* typically grows intermixed with other vegetation, using other grasses, forbs and most frequently shrubs as support to grow taller. Given this physiology this significant result intuitively makes sense. As vegetation grows denser in response to project treatments *D. acuminatum* becomes out competed for space and thus its mean height is lowered. *D. acuminatum* mean height should be considered for inclusion as part of a long-term monitoring program.

Hudsonia tomentosa

In shrub habitats during the summer the mean height of *Hudsonia tomentosa* was significantly higher during 2004 and 2005 as compared to 2003 in both Partial and Total treatment areas (Table 18). This result indicates that upon exposure to rest from horse grazing *H. tomentosa*, a species very susceptible to trampling effects, begins to recover in height. This result is further supported by the fact that a similar increase in height was not evident in Control study sites. *H. tomentosa* should be considered for inclusion as part of a long-term monitoring program.

Lechea maritima

In shrub habitats during the summer *L. maritima* had higher mean height values in Total and Partial treatment areas as compared to Control treatment areas. This difference was significant for the Total-Control Tukey pair-wise comparison, however the Partial-Control Tukey pair-wise comparison was not, ($p=0.07>>0.0167$, see Table 17). This may have been due in part to the limited number of sample heights collected from Control treatment areas for this species. Recall that *L. maritima* had lower abundance in Control treatment areas. These results therefore, are presented for information purposes only, since further data are required to determine if *L. maritima* mean height is a vegetative parameter that is sensitive to grazing on Assateague. As a result, at this time it is not recommended that *L. maritima* mean height be considered for inclusion as part of a long-term monitoring program.

Morella spp.

In shrub habitats during the spring and in forest habitats during the summer, the mean height of *Morella* spp. was found to be significantly higher in Total treatment areas as compared to both Partial and Control treatment areas. These results indicate that the removal of lower *Morella* spp. vegetation caused by existing levels of deer herbivory on Assateague Island was sufficient enough to increase the mean *Morella* spp. height in both forest and shrub habitats. Furthermore, exposure to rest from deer herbivory resulted in the regeneration of *Morella* spp. shrubs at lower elevations. These results make *Morella* spp. a taxonomic group worthy of consideration for inclusion as part of a long-term monitoring program.

Smilax rotundifolia

In forest habitats during both spring and summer, the average height of *S. rotundifolia* was significantly higher in Control treatment areas as compared to both Partial and Total treatment areas. This result reveals that within the timeframe of this research, rest from horse herbivory allowed *S. rotundifolia* to decrease in mean height. Although, deer herbivory was found to be locally responsible for reductions in *S. rotundifolia* abundance

(Table 14) according to these results, it is the current level of horse herbivory on Assateague Island that acts to increase the average height of *S. rotundifolia*. In other words, rest from deer and horse herbivory as well as rest from horse herbivory alone resulted in sufficient regenerative growth of *S. rotundifolia* at lower elevations above the forest floor such that its mean height was lowered during both spring and summer. These results make the mean height of *S. rotundifolia* a vegetative parameter worthy of consideration for inclusion in a long-term monitoring program.

Solidago sempervirens

In shrub habitats during the summer, the mean height of *S. sempervirens* was significantly higher in Total treatment areas as compared to both Partial and Control treatment areas. Similar to the absolute abundance analysis results for this species, these results indicate that *S. sempervirens* mean height is sensitive to deer herbivory. The number of sample heights collected during the summer was limited however, especially from grazed treatment areas, therefore prior to incorporating the mean height of this species into a long-term monitoring program, further data should be collected in order to verify this result.

Browse Chi-squared Results and Discussion

The browse data collected from within Control and Partial treatment areas are summarized in Tables 19 through 21. Taxa abbreviations found in these Tables can be cross-referenced with species or taxonomic groups using Tables 5 or 6.

Table 19. Overall forest and shrub browse estimates, summary data presented for each habitat (Forest, Shrub) and treatment (Control, Partial) category, showing the number of stems observed during sampling (#Stm) and the percent of browsed stems (%Brw) for each species or taxonomic group (Taxa) encountered during sampling.

Browse Data 2003 - 2005								
Taxa	Forest				Shrub			
	Control		Partial		Control		Partial	
	# Stm	%Brw	# Stm	%Brw	# Stm	%Brw	# Stm	%Brw
BAHA					305	69.5	117	96.6
DIVI	103	35.0						
HUTO					57	0.0	35	0.0
ILOP	23	0.0						
MOSP	151	51.0	157	56.1	1408	59.5	1194	49.2
PITA	68	1.5	65	4.6	127	6.3		
RUSP					80	90.0	104	61.5
SMRO	2048	85.4	1717	81.8				
TORA	82	41.5	158	39.9	144	72.9	134	56.0
VACO	228	49.6			253	64.4	99	53.5
VIRO	30	70.0	27	92.6	2	50.0		
Other*	71	42.3	67	26.9	22	54.5	24	41.7
Total	2804	73.5	2191	73.1	2093	57.3	1707	52.8

* “Other” represents the combined number of stems from infrequent taxa that were encountered.

Chi-square analyses of the browse data were conducted across all species combined as well as on those species with at least 30 observed stems in each treatment category during all rounds of sampling. These analyses did not reveal any significant differences in browse frequency between Control and Partial treatments across all browse species or for any individual species. Chi-square analyses did reveal that *Smilax rotundifolia* was browsed at significantly higher than expected frequencies in the Partial treatment areas of forest study sites ($X^2_{\text{SMRO Partial}} = 6.68 > 5.99 = X^2_{\alpha=.05,\,2}$). Chi-square analyses also revealed that *Morella* spp. was browsed at less than expected frequencies in both the Partial ($X^2_{\text{MYSP Partial}} = 15.04 > 5.99 = X^2_{\alpha=.05,\,2}$) and Control ($X^2_{\text{MYSP Control}} = 30.55 > 5.99 = X^2_{\alpha=.05,\,2}$) treatment areas of forest study sites.

Table 20. Forest browse estimates by treatment and year, showing the number of stems observed during sampling (#Stm) and the percent of browsed stems (%Brw) for each species or taxonomic group (Taxa) encountered during sampling.

Forest Browse Data												
Taxa	Control						Partial					
	2003		2004		2005		2003		2004		2005	
	# Stm	%Brw	# Stm	%Brw	# Stm	%Brw	# Stm	%Brw	# Stm	%Brw	# Stm	%Brw
DIVI	31	71.0	33	39.4	39	2.6						
ILOP					23	0.0						
MOSP	44	65.9	68	55.9	39	25.6	83	62.7	43	58.1	31	35.5
PITA			26	3.8	42	0.0	21	0.0	22	13.6	22	0.0
SMRO	731	92.6	718	88.0	599	73.5	617	90.3	645	78.6	455	74.7
TORA	29	58.6	24	50.0	29	17.2	75	42.7	21	57.1	62	30.6
VACO							102	74.5	54	40.7	72	20.8
VIRO	30	70.0					27	92.6				
Other*	26	65.4	25	20.0	20	40.0	12	41.7	29	20.7	26	26.9

* "Other" represents the combined number of stems from infrequent taxa that were encountered.

Table 21. Shrub browse estimates by treatment and year, showing the number of stems observed during sampling (#Stm) and the percent of browsed stems (%Brw) for each species or taxonomic group (Taxa) encountered during sampling.

Shrub Browse Data												
Taxa	Control						Partial					
	2003		2004		2005		2003		2004		2005	
	# Stm	%Brw	# Stm	%Brw	# Stm	%Brw	# Stm	%Brw	# Stm	%Brw	# Stm	%Brw
BAHA	160	72.5	125	69.6	20	45.0	47	100.0	47	93.6	23	95.7
HUTO					57	0.0					35	0.0
MOSP	527	69.8	368	45.9	513	58.7	455	52.5	390	37.9	349	57.3
PITA			40	17.5	87	1.1						
RUSP	60	98.3			20	65.0	53	67.9	23	43.5	28	64.3
TORA	30	66.7	84	72.6	30	80.0	22	72.7	82	53.7	30	50.0
VACO	49	85.7	109	49.5	95	70.5			79	41.8	20	100.0
VIRO					2	50.0						
Other*	19	52.6	3	66.7			12	75.0	1	100.0	11	0.0

* "Other" represents the combined number of stems from infrequent taxa that were encountered.

Deer herbivory was responsible for the vast majority of browse activity that occurred in shrub and forest study sites. The percent of browsed stems in Control versus Partial treatment areas were: 73.5% v. 73.1% respectively in forest study sites and 57.3% v. 52.8% respectively in shrub study sites indicating that deer are responsible for more than 90% of the observed browse in each habitat.

Chi-square analyses revealed that in forest habitats *Smilax rotundifolia* was preferred as a browse species while *Morella* spp. was not. A similar result was not found for *Morella* spp. in shrub study sites where it represented a larger proportion of the available browse.

The limited size of project treatment areas did not allow for adequate replication of all browse species during data collection. Additionally, it is possible that some browse species may exhibit delayed responses to changes in browse intensity which were not detected during the limited, three year, time span of this research. As a consequence, these results should be considered to be preliminary and best suited for planning additional browse research, which is recommended prior to further consideration of vegetative responses to changes in browse intensity as part of a long-term monitoring program. Additional browse research could easily be conducted on any browse species that is eventually included in the long-term monitoring program as a result of its significant abundance or height responses to project treatments.

Cover-board Chi-square Results and Discussion

Table 22 presents the estimated average percent cover by half meter height intervals between 0 and 2 meters, in addition to the overall average percent cover, by habitat, year and treatment. Table 23 shows the significant chi-square results ($X^2_{test} > X^2_{\alpha=.05, 2} = 5.99$) that occurred during comparisons between treatments.

Table 22. Forest and shrub cover-board estimates, showing estimates for each half meter height interval category, as well as the overall (2 meter) height of the cover-board.

Percent Cover by Habitat, Year and Height							
Year	Height Interval (m)	Forest			Shrub		
		Control	Partial	Total	Control	Partial	Total
2003	0.0-0.5	61	55	48	94	98	92
	0.5-1.0	42	39	33	34	37	23
	1.0-1.5	38	42	38	23	24	12
	1.5-2.0	32	39	35	14	12	6
	0.0-2.0	43	44	39	41	43	33
2004	0.0-0.5	61	62	68	87	86	91
	0.5-1.0	46	41	36	60	46	55
	1.0-1.5	44	36	29	31	26	33
	1.5-2.0	38	34	23	21	13	21
	0.0-2.0	47	43	39	50	43	50
2005	0.0-0.5	52	53	67	83	83	82
	0.5-1.0	37	31	40	52	53	44
	1.0-1.5	33	28	31	36	32	29
	1.5-2.0	32	27	24	24	20	19
	0.0-2.0	39	35	41	49	47	43

Table 23. Chi-square (X^2) results for cover-board estimates. Tot = Total, Par = Partial and Con = Control. During these analyses Con estimates were used as expected values during Tot v. Con and Par v. Con comparisons, while Par estimates were the expected values for Tot v. Par comparisons. ($X^2_{\alpha=.05,\,2} = 5.99$). Only significant results are shown.

Habitat	Height Interval (m)	Significant Percent Cover X^2 Results		
		Tot v. Con	Par v. Con	Tot v. Par
Forest	0.0-0.5	7.8		
	0.5-1.0			
	1.0-1.5			
	1.5-2.0	8.0		
	0.0-2.0			
Shrub	0.0-0.5			
	0.5-1.0			8.5
	1.0-1.5	7.0		8.1
	1.5-2.0			7.1
	0.0-2.0			

Over the three years of this project, overall cover, between 0-2m, was not found to have significantly increased in response to lower levels of ungulate herbivory in either forest or shrub habitats. X^2 analyses of average cover estimates from half meter elevation increments of the cover-board (0m-0.5m, 0.5m-1.0m, etc.) did however reveal significant differences.

Maintaining consistency during cover-board data collection was difficult between years since different observers collected data each year. Recall that each 0.5m increment in cover-board height was subdivided into twenty-five $10m^2$ sections. The observer was asked to record the number of $10cm^2$ sections that were uncovered at each placement of the cover-board. Inevitably some $10cm^2$ sections were only partially covered which presented an opportunity for subjective observer bias to occur. Additionally, the limited expanse of project treatment areas, limited sample size (n=30 boards per treatment) within each treatment, and variations in the topography and location of woody cover within treatment areas all potentially influenced cover-board sampling results.

The no-significant-change in overall percent cover finding is arguably the most reliable cover-board analysis result because data from the entire cover-board (0-2m, 100-$10cm^2$ sections) were used. By comparison, the significant cover analyses results from the 0.5m height increments of the cover-board used estimates generated from sampling 25-$10cm^2$ sections of the cover-board. This smaller number of sampled sections is more likely to have been influenced by the factors mentioned above.

During this project, casual observation would suggest that vegetative cover increased most at lower elevations in Total treatment areas in forested study sites. This is supported by the significant chi-square result found for the forested 0.0-0.5m height interval, see table 23. Looking at table 22 you can see that in forest study sites during 2003 cover at the 0.0-0.5m height interval was initially estimated to be higher in Control treatment areas (as compared to Total treatment areas) but by 2005 this had reversed and cover was estimated to be higher in Total treatment areas at this elevation.

The use of cover-board sampling techniques proved to be problematic within the limited confines of this project's treatment areas. However the use of cover-board sampling techniques should be considered as part of a long-term monitoring program especially over a more appropriate spatial scale and with better replication within habitats. Over the long-term, cover-board sampling may prove to be an efficient method for monitoring changes in the amount of vegetative cover in different island habitats as the island responds to changes in the levels of ungulate herbivory.

Distance-Sampling Results and Discussion

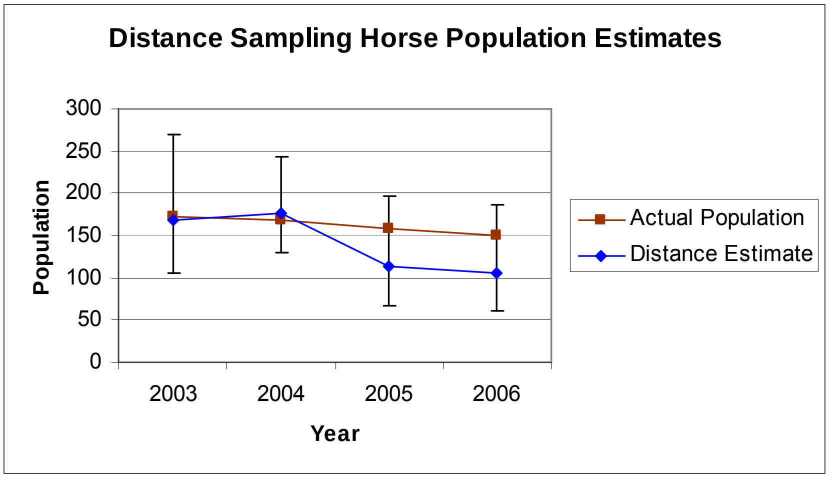
The 2003 through 2006 distance-sampling estimates for the Assateague Island National Seashore's winter feral horse, sika deer and white-tailed deer populations are given in Table 24. The Seashore closely monitors the horse population and during the winter, when distance-sampling was conducted, the actual horse population was known to be 172, 168, 159 and 150 from 2003 through 2006 respectively.

Table 24. Distance-sampling estimates of horse, sika deer and white-tailed deer abundance, along with lower and upper 95% confidence intervals (CI), at Assateague Island National Seashore from 2003 to 2006.

Species	Year	Population Estimate	Lower 95% CI	Upper 95% CI
Horses	2003	168	105	270
	2004	177	129	244
	2005	114	66	196
	2006	106	60	186
Sika Deer	2003	343	226	519
	2004	368	247	546
	2005	401	254	632
	2006	342	210	555
White-tailed Deer	2003	122	69	215
	2004	113	60	212
	2005	104	58	187
	2006	116	58	230

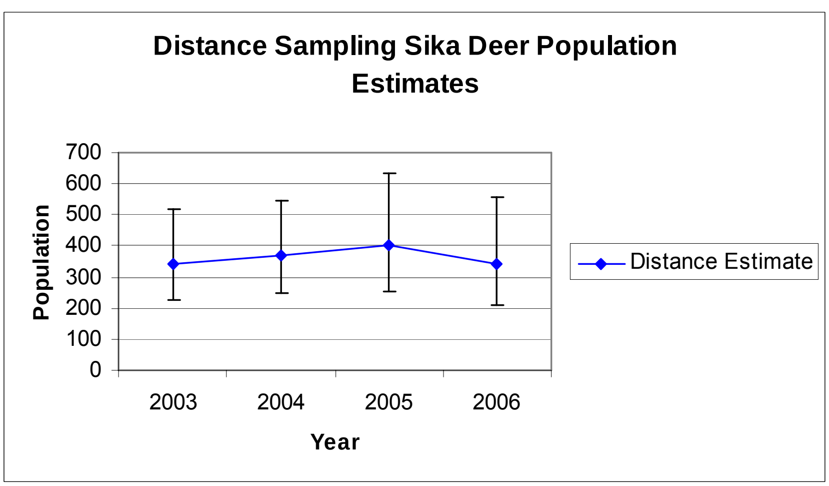
The distance-sampling results are presented graphically in Figures 16 - 18. Figure 16 shows that the known horse population was consistently within the 95% confidence interval of the Distance® generated horse population estimates. These results lend confidence towards the use of Distance® as an effective means of generating ungulate population estimates on Assateague Island. Recall however, that during data collection horse locations were less likely to be influenced by observer presence than those of sika and white-tailed deer. This was primarily due to differences in behavior, as deer would occasionally sound alarms and/or flee prior to being observed, which inevitably affected their location upon detection as well as their detection rate. This behavior is problematic since one assumption of the Distance® program is that animals are detected in their initial locations. Therefore during distance-sampling, when this assumption was deemed likely to have been violated, the data were discarded and the transect was later resurveyed.

Figure 16 Distance-sampling horse population estimates and horse census data for the Maryland end of Assateague Island mid-winter 2003 through 2006



Despite the inherent difficulties of using distance-sampling, the population estimates it has generated have provided a more complete understanding of the intensity and types of herbivory that resulted in the observed vegetative responses to project treatments. Recall that in region 2, (Figure 9) permitted deer hunting includes: shotgun, muzzleloader and archery seasons, while in region 1 only archery hunting is allowed. Although sika and white-tailed deer from regions 1 and 2 exhibited similar behaviors towards observers in the field, over the four years during which distance-sampling results are presented, sika and white-tailed deer were observed 23% and 36% more frequently in region 1 respectively (on a per unit effort basis). This indicates that both sika deer and white-tailed deer utilize those areas of Assateague Island that experience lower hunting pressures with greater frequency. Each of this project's study sites were located within region 2, or that section of Assateague Island National Seashore that is subjected to the highest deer hunting pressures and correspondingly is likely to experience the lowest levels of deer herbivory. This is important to bear in mind while contemplating the vegetation results presented here.

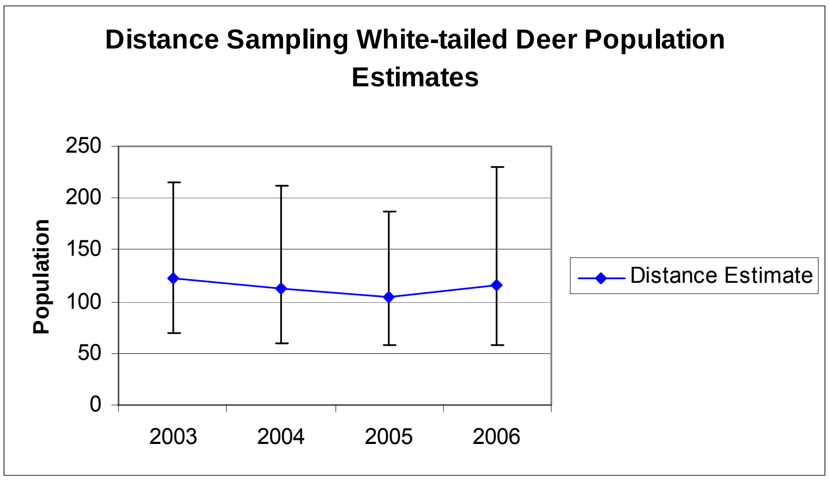
Figure 17 Distance-sampling sika deer population estimates for the Maryland end of Assateague Island mid-winter 2003 through 2006



The distance estimates were remarkably consistent between years. For example the estimated number of sika deer per square mile was 24, 26, 28 and 24 for 2003, 2004, 2005 and 2006 respectively, while white-tailed deer estimates were 9,8,7,8 for the same years respectively. The lack of year to year variation in the distance-sampling deer population estimates is seemingly supported by the consistency of the deer harvest recorded during this same period, shown in Table 25.

The average estimated deer density over all years was 26 sika and 8 white-tailed deer per square mile (95% confidence interval: 17-40 sika and 4–15 white-tailed deer per square mile). Combining these estimates (34 deer/sq. mile, 95% CI: 21-55) reveal a moderate to high mid-winter deer density for Assateague Island, at least according to research from temperate, forested, mainland locations (Tilghman 1989) which may, or may not, be applicable to Assateague Island's mid-Atlantic barrier island landscape. It is important to realize that these estimates reflect a low point in the annual population cycle for Assateague Island deer, since transects were conducted post hunting season yet prior to the birthing season each year.

Figure 18 Distance-sampling white-tailed deer population estimates for the Maryland end of Assateague Island mid-winter 2003 through 2006.



Presuming a healthy reproductive population with good survivorship and an equal sex ratio, it is reasonable to assume that both deer populations expand during the growing season by as much as 50%. This would result in high deer densities during the growing season when this project's vegetative data were collected.

Table 25 Assateague Island National Seashore deer harvest data

Assateague Island National Seashore's Deer Harvest		
Hunting Season	Sika Deer	White-tailed Deer
2002-2003	135	closed
2003-2004	148	closed
2004-2005	140	15
2005-2006	144	24

During this project distance-sampling transects were only conducted from late afternoon to dusk. During sampling it became apparent that in addition to time of day, deer activity was also strongly influenced by prevalent weather conditions, with deer being considerably more active on calm and comparatively warm days. This increased activity made it more likely to observe deer during sampling. As a result, I would suggest that during the winter, future distance-sampling could be conducted on good weather days, beginning after the sun has warmed up, around midmorning, and continuing throughout the afternoon and evening. This would help alleviate some scheduling difficulties, since observers would be able to conduct transects during normal working hours. It would also have the added advantage of shortening the distance-sampling period. Should this recommendation be implemented however, care should be taken not to survey neighboring transects on the same day in order to avoid the possibility of observers affecting the distribution of sampled deer.

At the time of the writing of this report, a deer radio telemetry research project is also being conducted that will provide an opportunity to verify (or not) the distance-sampling deer population estimates using independent abundance estimation techniques.

Conclusions

This research demonstrates that certain vegetative parameters at ASIS are sensitive to existing levels of deer herbivory while others are more sensitive to current levels of horse herbivory or exhibit a cumulative response to the combined effects of both grazer groups. This research further indicates that the development of long-term vegetation monitoring protocols designed to quantify the ongoing effects of ungulate herbivory at ASIS is feasible.

The vegetative parameters that exhibited significant responses to project treatments included annual and perennial species. Generally speaking, annual plant species tend to be prone to large fluctuations in abundance and productivity due to environmental variables unrelated to ungulate herbivory, such as variations in the seasonal amount and timing of rainfall. Although their abundance is sometimes dramatically affected by such environmental variables, under comparable conditions annual plant species are most likely to provide the best short-term measure of response by the vegetative community to changes in ungulate management.

Perennial plant species on the other hand, though certainly affected by environmental variables, tend not to fluctuate in abundance or height as dramatically as annuals and therefore are more likely to provide better information relating to long-term vegetative trends in response to ASIS's ungulate management. Therefore it will be important to include both annual and perennial plant species in any long-term vegetation monitoring program.

Whenever possible, the sampling design for a selected vegetative parameter should target the parameter instead of being designed to generally monitor plant communities in order to later look at the parameter in question, as was done during this study. For example, should *A. rubrum* saplings in forest habitats be selected, an effective monitoring design should target locations in the vicinity of sexually mature *A. rubrum* trees, instead of randomly monitoring for *A. rubrum* saplings throughout forested habitats. Such targeted data collection will facilitate efficient data collection, help reduce sampling variation and thereby minimize the amount of data required to detect a vegetative response to ungulate management. This approach will however, require an initial investment of time and energy in order to locate potential sampling locations for each selected vegetative parameter, so that an adequate sampling design can be developed.

The sampling design for each selected vegetative parameter should also consider variations in horse and deer density along the longitudinal axis of Assateague Island and if necessary stratify accordingly. Additionally, care should be taken to assure adequate replication within each strata. This research provides vegetative parameter estimates that should be used during the development of sampling strategies. Data from each selected vegetative parameter should initially be analyzed skeptically in order to reconfirm predicted responses, since it is possible ($\alpha = 0.05$) that some of the significant responses presented herein do not actually reflect a response to herbivory.

The development of vegetation monitoring protocols will be valuable to the successful implementation of an adaptive management program. Such a program will conceivably use the sensitive vegetative parameters identified during this research to monitor and understand ungulate population trends, as well as the island's vegetative community response to varying intensities of ungulate herbivory, as influenced by changes in ASIS's deer and horse management. Ultimately through the establishment of such an adaptive management program ASIS hopes to more comprehensively understand and address issues relating to the management of its diverse assemblages of unique and sensitive, flora and fauna communities.

The Distance® generated deer abundance estimates, along with those generated via different means, will allow ASIS to attribute observed vegetative responses to quantifiable changes in the levels of herbivory. This will help managers to better understand how different vegetative parameters respond to changes in the intensity of deer herbivory.

The results of this research indicate that both white-tailed deer and sika deer are selective herbivores that typically choose specific taxa within their environments upon which to forage. ASIS horses on the other hand appear to be more generalists, meaning their diet typically consists of a broad sampling of the plant species that are present in areas where they forage. The impacts of each of these unique foraging behaviors manifest themselves within island plant communities through changes in vegetative parameters such as community composition, individual species abundance, height, percent browse or even through more general measures of habitat change, such as vegetative cover.

Understanding white-tailed deer and sika deer habitat utilization patterns as well as their overall abundance will help to further attribute deer vegetation responses to specific deer species. A collaborative research project between the US Geological Survey, Penn State University and the NPS is currently underway (implemented 2006 - 2007) that is investigating these aspects of Assateague Island deer ecology. The knowledge gained during these complementary deer research projects will help park managers better understand the ecological role of each of Assateague Island's deer species. Ultimately this new understanding will help managers to successfully maintain the long-term viability of Assateague Island National Seashore's biotic communities.

Support for this project (PMIS 86455) has been provided by the NPS through Natural Resource Protection Program–Regional Block Grant Funds, Recreational Enhancement Act Funds and Assateague Island National Seashore. The testing phase of the preliminary monitoring protocols developed as a result of this research is currently funded through FY08 after which time it is anticipated that the project will transition into a long-term adaptive management program to be implemented by ASIS.

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