

Assateague Island National Seashore Low Salt Marsh Monitoring Progress Report January 2008



By

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Abstract

Four long-term monitoring sites were established in low salt marsh habitats at Assateague Island National Seashore (ASIS) in order to monitor the effects of prolonged exposure to horse grazing. At each site paired grazed and exclosed treatment areas were established. The sites were monitored tri-annually from 1994 through 2006, a period during which ASIS experienced historically high levels of horse abundance. Data analyses revealed that horse herbivory significantly reduced aboveground aerial vegetation by 45%. The monitoring site that consistently experienced the greatest horse grazing intensity exhibited a significantly higher stem density of *Spartina alterniflora*, the dominant low salt marsh grass species. During 2006, a dieback event also influenced the development of low salt marsh habitats. This dieback resulted in an overall significant reduction in salt marsh productivity, however three of the project's four study sites demonstrated that areas exposed to long term rest from horse grazing exhibited a significantly improved capacity to tolerate the effects of the dieback, while the fourth study site exhibited no improvement.

Introduction

Assateague Island has been continuously exposed to horse (*Equus caballus*) herbivory for more than three centuries. This report presents the results of a long term monitoring project designed to document the influence of horse herbivory in Assateague Island National Seashore's (ASIS) low salt marsh habitats. Throughout the monitoring period (1994 - 2006) ASIS supported an abundant, free ranging horse population.

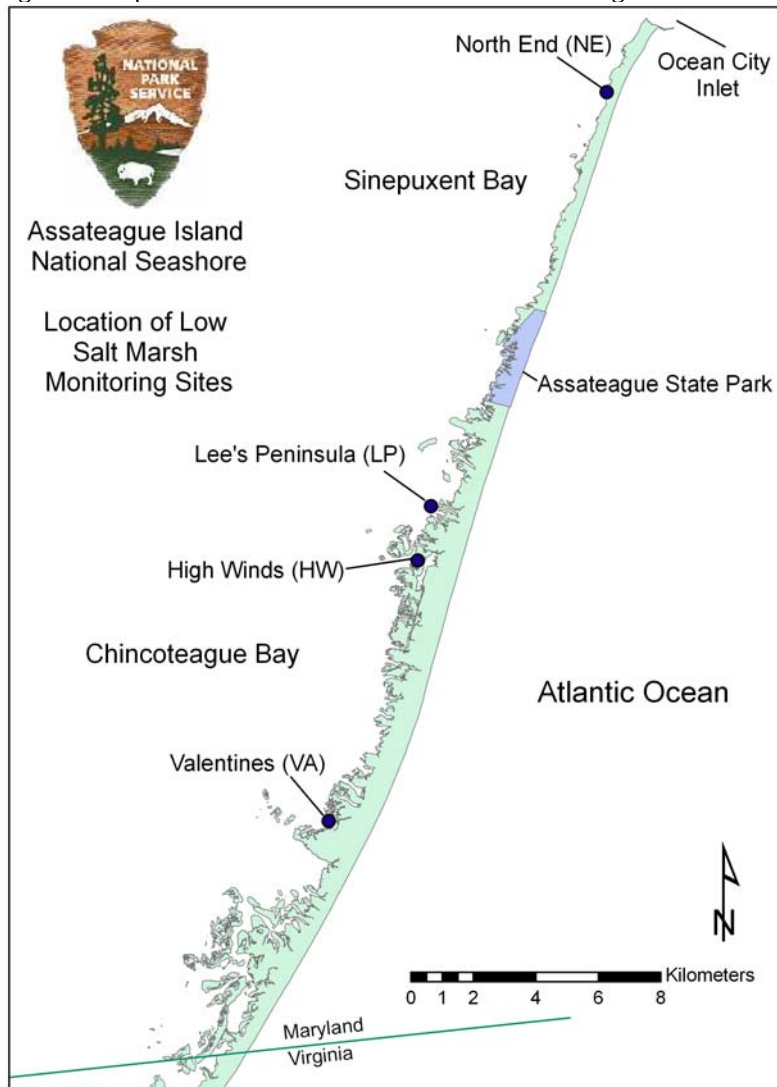
Assateague Island is a 58 km long barrier island that extends from the Ocean City Inlet in Worcester County, Maryland south to the Chincoteague Inlet in Accomack County, Virginia. In addition to the two inlet systems, Assateague Island is bordered to the east by the Atlantic ocean and to the west by Sinepuxent bay and Chincoteague bay. Most of the Maryland portion of the island (35+ km) is managed by the National Park Service (NPS) as Assateague Island National Seashore however the Maryland Department of Natural Resources (MDNR) does manage a three kilometer section of the island as Assateague State Park. The southern (Virginia) end of the island is managed by the U.S. Fish and Wildlife Service (FWS) as Chincoteague National Wildlife Refuge (CNWR).

Prior to ASIS' establishment in 1965, the island was also periodically exposed to intensive livestock grazing in addition to being continually exposed to varying levels of horse herbivory. In addition, white-tailed deer (*Odocoileus virginianus*) are native to the island and a population of sika deer (*Cervus nippon*) that was first introduced to the island during the 1920's, has by now become naturalized and abundant.

In 1968, the newly established National Seashore acquired ownership of 28 resident horses from which today's ASIS horse population is descended (Eggert, et al 2005). By

the mid 1980's the population had grown to more than 150 horses and the park began to be concerned about the impacts horses were having on other island resources. In response, the park initiated several projects intended to document the threats posed by the abundant horse population and also to determine how best to control its continued expansion. During subsequent years, while these projects were being developed and implemented the ASIS horse population eventually peaked at 179 individuals in 2002. The current, December 2007, ASIS horse population stands at 134.

Figure 1. Map of the location of low salt marsh monitoring sites at Assateague Island National Seashore.



A second horse population, which is owned and managed by the Chincoteague Volunteer Fire Department, exists on CNWR. The two populations are kept separate by a fence located along the Maryland-Virginia state line. The results in this report pertain only to the influence of the ASIS horse population.

The commencement of the ASIS horse population's decline is the result of a contraceptive program described by Kirkpatrick (1995). This program inoculates mares with a porcine zona pellucida (PZP) vaccine which acts as a reversible contraceptive. In order to maintain infertility, mares need to receive booster inoculations each year. This program provides managers with an effective tool to manage population growth.

Early investigations into the influence of horse grazing on island resources revealed many significant detrimental effects in various island communities. Stribling (1989), Furbish (1990) and Furbish, et al (1994) documented horse related impacts in low salt marsh communities while Salikar (1997) and DeStoppelaire (2002) documented the effects of horse grazing on island dune habitats and more recently Sturm (2007a) demonstrated the effects of horse grazing in island forest and shrub habitats.

This long term monitoring project arose after research showed that low salt marsh habitats were being especially heavily impacted. For example, Stribling (1989) found that horse grazing altered low salt marsh nutrient cycling while Furbish (1990) and Furbish, et al (1994) found that horse grazing reduced aboveground biomass, altered low salt marsh plant and animal species composition and at high intensities may change the phenotypic expression of the low salt marsh's dominant grass species, salt marsh cordgrass (*Spartina alterniflora*). A brief history of this long term monitoring program, follows.

During 1991 two monitoring sites were established in areas of the island known as Lee's Peninsula (LP) and High Winds (HW). Exclosure and control treatment areas were established at these sites, with treatment areas measuring 50m x 50m. Later, during 1993, two additional study sites were established in the North End (NE) and Valentines (VA) areas of the island, see Figure 1. Inside the exclosures at each monitoring site, the treatment areas were surrounded by buffers in order to accommodate the occasional horse sticking its head through the exclosure fence to graze. Also, throughout this project, deer could move freely in and out of all exclosed treatment areas.

The project's monitoring sites are situated from North to South in the following order NE, LP, HW and VA, see Figure 1. Within Sinepuxent bay and Chincoteague bay ocean tidal influence varies considerably along a North-South gradient. Nearer the inlet (Sinepuxent bay) tides tend to be heavily influenced by the ocean, typically fluctuating between one and two feet per tidal cycle, while further south towards the middle of the island's length, the ocean's influence is considerably less with ocean derived tidal fluctuations on a scale of inches. Tides in this mid-island region are more heavily influenced by prevailing rain and wind conditions. Prevailing winds can blow bay waters onto (or off) of the marshes for prolonged periods and even after the winds subside, it may take days for the bay to once again achieve equilibrium. Understanding these subtleties of the coastal bay system adjacent to Assateague Island is important because they help to explain some monitoring results.

The North End is a term that generally refers to the northernmost 10 km of Assateague Island. This section of the island is frequently subjected to overwash, which tends to

encourage the development of new low salt marsh habitats via the frequent influx of water deposited sands on Assateague's bay side. However, the comparatively narrow width of this section of the island (+/- 300 m) is not sufficient to permit the development of expansive low salt marsh habitats. Because of the limited expanse of low salt marsh habitats along the North End, the size of the NE treatment areas were reduced to 30m x 30m.

The LP monitoring site is isolated and difficult to reach (perhaps for horses too) since it is located at the western end of a long and narrow peninsula. The LP study site is bordered immediately to the north by a gut, however to the south, the treatment areas are bordered by a narrow, elevated *Iva frutescens* (shrub) community, which in turn immediately borders a second gut to the south. During the winter of 2004, a corner of the LP enclosure was destroyed when ice sheets from the bay washed ashore. The enclosure was repaired during the following spring, however a triangular portion of the former treatment area inside the enclosure, measuring approximately 60m² was eliminated from the treatment area due to erosion/bay encroachment.

The HW monitoring site is located in an expansive marsh. Unlike the other monitoring sites the HW treatment areas are located comparatively far apart, being situated over 100 meters distant from one another, on the same contiguous marsh habitat. The HW marsh is unique because a constructed causeway traverses it from east to west. The causeway originally served as an access road to the "High Winds" hunting lodge, which was constructed in an isolated patch of maritime forest habitat on the western side of the island. The lodge is now in a state of disrepair, however the causeway remains largely intact and continues to alter the marsh's natural hydrology by severely restricting the north-south flow of water and sediments.

The HW enclosure treatment area occurs just south of the aforementioned maritime forest habitat. The HW control (grazed) treatment area is located further out on the open marsh. It is bordered to the north and east by a large lagoon that has already encompassed much of the original treatment area. Today the majority of the HW Control treatment area is open standing water or mud flat. The HW Control site is also bordered to the southwest by the terminal end of a gut that has been eroding sections of the adjacent marsh. Though this gut has not yet reached the treatment area, it appears to be only a question of time. Because of the deteriorated condition of this treatment area, a new HW control treatment area will have to be established prior to a subsequent round of data collection or the entire monitoring site will have to be abandoned.

The VA monitoring site is located on an expansive low salt marsh area just north of Valentine cabin. Both treatment areas are located in close proximity to one another. The VA monitoring site is located furthest away from an island inlet and therefore is subject to the least amount of ocean tidal influence. Additionally, the treatment areas at the VA monitoring site originally measured 40m x 40m, which like the NE was smaller than the treatment areas at both the original LP and HW study sites. During the establishment of each monitoring site a prerequisite was that each paired plot not contain ditches from a

failed 1930's mosquito reduction project. Due to remnant ditches from this project, the largest suitable paired study site in the Valentine area measured 40m x 40m.

Since the establishment of this long-term monitoring project, other factors that are also affecting Assateague Island's low salt marsh communities have increasingly become of interest to the park. Specifically, ASIS is interested in understanding how decades of human derived interruption of cross-island sedimentation processes have affected the low salt marsh's ability to respond to threats posed by global warming and associated sea-level rise. Here, understanding marsh elevation dynamics are of particular interest. In order to be able to monitor marsh elevation in areas that have been exposed to long term rest from horse grazing, during 2006 the HW, LP and VA treatment areas were reduced by first randomly selecting an existing treatment corner and then establishing a new 30m x 30m treatment area within the prior larger treatment areas. This effectively made all treatment areas the same size and created an area inside the three larger exclosed areas where elevation monitoring sites can be established. Table 1 and Figure 2 summarize the size changes that have occurred in this project's various study sites.

Figure 2. Sizing of the NE, LP, HW and VA treatment areas throughout the low salt marsh long-term monitoring project.

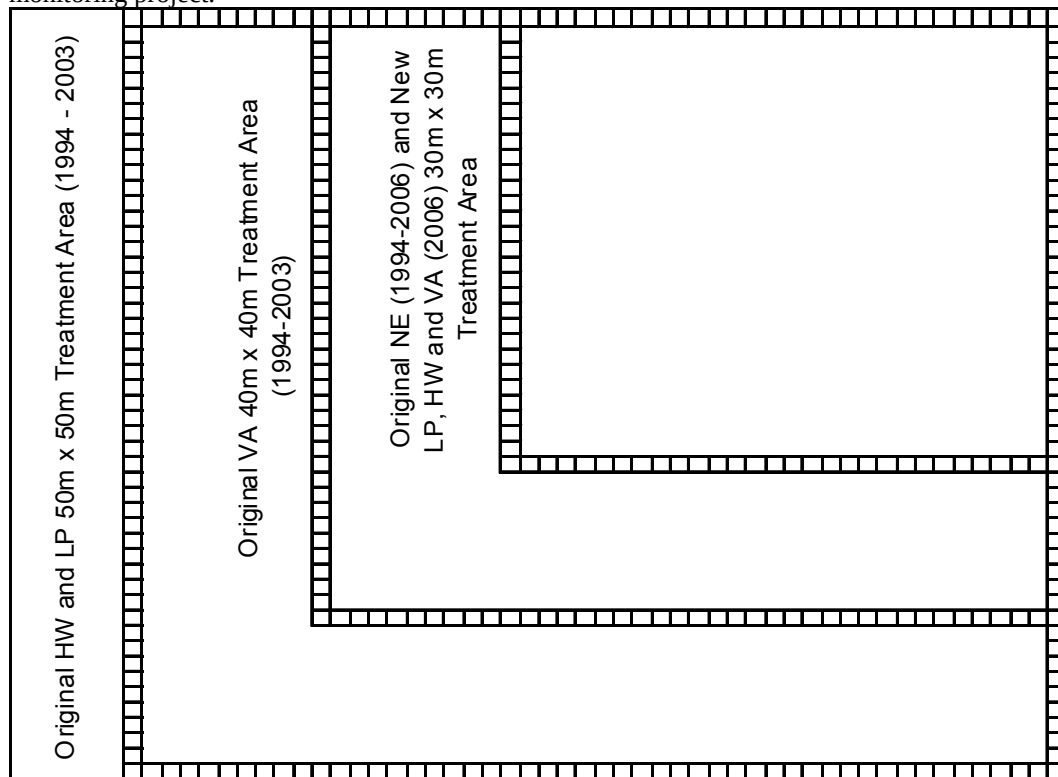


Table 1. Size of monitored treatment area by year.

Year Established and Monitoring Year		Long-term Low Salt Marsh Monitoring Sites			
		NE	HW	LP	VA
Year established		1993	1991	1991	1993
Monitoring Year	1994	30m x 30m	50m x 50m	50m x 50m	40m x 40m
	1997	30m x 30m	50m x 50m	50m x 50m	40m x 40m
	2000	30m x 30m	50m x 50m	50m x 50m	40m x 40m
	2003	30m x 30m	50m x 50m	50m x 50m	40m x 40m
	2006	30m x 30m	30m x 30m	30m x 30m	30m x 30m

Methods

Data Collection

Data collection followed the stratified random design described by Furbish (1991) although the sample quadrat size was reduced from 1m² to 1/16m² because Furbish, et al (1994) found that the smaller quadrat size was optimal for sampling. All sampling techniques described in Furbish (1991) were correspondingly adjusted to accommodate the smaller quadrat size. Each sampling round occurred during the fall. The techniques used during this monitoring project are further elaborated below.

First, a baseline was established along the western (or northwestern) boundary of each treatment area, depending on each individual treatment area's orientation. A measuring tape was run along the baseline and a second measuring tape was run along the side opposite the baseline. Each of these lines began with 0m in the northern (or northeastern) corner. The baseline was then divided into five equal line segments and a sampling transect was randomly established within each segment. Each segment equaled 6m (= 30m/5) for all treatment areas during 2006, however during prior rounds of data collection, line segment lengths equaled 10m (=50m/5) at both LP and HW and 8m (=40m/5) at VA.

Prior to establishing a sampling transect, it was important to determine the location of other transects from neighboring baseline segments in order to prevent unintentional trampling of other sample locations. A transect starting point was selected along each baseline segment by selecting a random 0.25m interval along its length (ex: 0.0m, 0.25m, 0.5m, 0.75m, etc...). At each designated starting location a third measuring tape was run perpendicular to the baseline across the treatment area starting with 0m at the baseline. Finally, along each of these five transects five random 25cm sampling locations were selected. Therefore, during each round of data collection, within each treatment area a total of five randomly stratified transects were sampled at five random locations using the methodology described below.

At each location a $\frac{1}{16}\text{m}^2$ quadrat (0.25m x 0.25m) was sampled. Within each quadrat all species were identified and their percent cover was visually estimated. Then, using a pair of hand held clipping shears, the aerial vegetation within the quadrat was removed and placed in paper bags, in order to later determine aboveground biomass. During clipping, the vegetation was cut at 2-3cm above the marsh soil surface. Care was taken only to

include vegetation from live stems and not to include marsh muck in the clippings. Finally, within each quadrat the number of stems from each species were counted. Typically, this was most easily accomplished by counting residual stems (or culms) left after clipping.

Vegetation samples that were not immediately able to be placed inside a drying oven were hung inside an enclosed shelter on clotheslines with the bags open in order to allow them to begin to air dry. Drying oven use occurred in a controlled indoor environment. Oven drying temperatures were maintained at around 90° F. A sample was deemed to be dried when its weight on subsequent days differed by 0.1g or less. In order to determine the final dry weight of a sample the bag and sample were first weighed together, then the vegetation was removed and the bag was re-weighed. The sample's dry weight was calculated as the initial weight less the weight of the bag.

Data Analyses

The experiment-wise error rate (α_e) used during data analysis was 0.05 and all post-hoc analyses 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. ANOVA, Tukey and Pearson's correlation analyses were performed using SYSTAT® 11 statistical software.

Experiment-wise multifactor analyses of variance (ANOVAs) were performed on the low salt marsh monitoring data. During these analyses, the five transects per treatment were considered to be the primary sample unit, each of which was sub-sampled at 5 random locations. During the data analyses, potential sources of variation included years - (1994, 1997, 2000, 2003, 2006), treatments - (Exclosure and Control) and the four replicate study sites (NE, LP, HW and VA). Standard assumptions applied. Specifically it was assumed that samples were drawn from a normal population and 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.

Results and Discussion

Primary Productivity

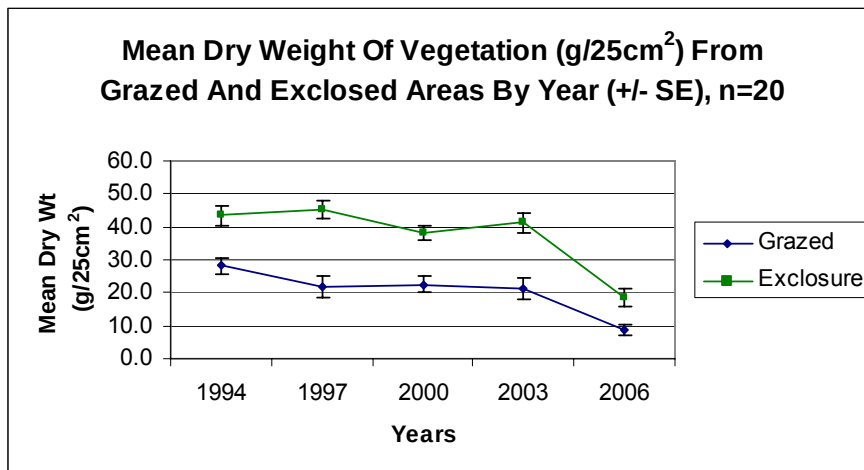
Horse grazing significantly reduced low salt marsh primary productivity. The overall mean dry weight of aerial vegetation from the 25cm² samples in grazed and exclosed treatment areas were 20.5g and 37.4g respectively. This represents a 45% reduction in primary productivity over all monitoring sites and years. Grazed treatment areas consistently had less aerial vegetation as compared to exclosed areas, with one exception (LP 1994, see Table 2).

Table 2. Mean weight (g) of dried vegetation per 25 cm² from treatment areas grazed by horses and exclosure treatment areas that were exposed to rest from horse grazing, along with the associated standard error (Std Error) by year. n=5 transects per treatment. Each transect value was the average of 5 randomly sampled 25cm² locations.

Monitoring Site	Treatment	1994		1997		2000		2003		2006	
		TDW (g)	Std Error	TDW (g)	Std Error	TDW (g)	Std Error	TDW (g)	Std Error	TDW (g)	Std Error
NE	Grazed	12.3	1.3	8.8	1.6	14.1	4.0	10.7	3.7	10.2	2.7
	Exclosure	43.3	1.1	49.0	4.0	43.7	0.7	49.6	1.1	31.3	2.0
LP	Grazed	34.5	2.0	29.3	7.5	28.1	6.2	42.0	3.5	0.0	0.0
	Exclosure	31.4	3.2	52.1	5.7	36.3	7.1	55.3	2.5	0.0	0.0
HW	Grazed	31.9	2.0	18.8	6.8	25.6	4.9	13.7	4.6	10.9	3.9
	Exclosure	35.2	1.9	36.5	3.2	36.5	3.7	19.7	1.8	24.8	1.2
VA	Grazed	33.7	1.5	31.0	4.3	21.9	2.3	19.0	2.2	13.6	3.2
	Exclosure	64.2	3.0	43.7	5.9	36.7	3.7	40.1	2.1	17.7	2.4
All Sites	Grazed	28.1	2.3	22.0	3.3	22.5	2.4	21.4	3.3	8.7	1.8
	Exclosure	43.5	3.1	45.3	2.6	38.3	2.2	41.2	3.2	18.4	2.8

Upon exposure to long term rest from horse grazing, low salt marsh aboveground biomass increased significantly (Table 2 and Figure 3). Even in very degraded areas where horse grazing intensities were highest, such as the NE, the exclosed treatment area quickly, and thereafter consistently exhibited primary production levels comparable to those of other monitoring sites.

Figure 3. Mean weight (g) of dried vegetation per 25cm² in areas grazed by horses and exclosure treatment areas (+/- 1 Standard Error, n=5 transects) by year.



The observed higher levels of productivity in exclosed sites can not solely be explained as a direct response to a reduction in the amount of forage consumed by horses. The increase is also partially attributable to a reduction in horse trampling effects and a corresponding increase in *S. alterniflora* regeneration via rhizomal expansion as well as via increased seed production (see page 12). Sturm (2007b) used this information to quantify the relative influence of horse grazing at varying horse population densities for the Maryland end of Assateague.

Table 2 and Figure 3 also reveal that there was a significant reduction in primary productivity during 2006 within both grazed and exclosed treatment areas. During August

through October 2006 Chincoteague and Sinepuxent Bays experienced a prolonged period of greater than predicted tidal cycles. This was due in part to the previously mentioned limited tidal flushing capacity of the bay system. Contemporary with these higher than predicted tidal events, during this period the region also experienced several significant rainfall events, which combined totaled 14.3 inches, nearly doubling the regions average for the period.

This combination of events resulted in a prolonged accumulation of standing water over the island's low salt marsh communities. Ultimately, during the fall of 2006, Assateague Island's low salt marshes experienced a large scale dieback. This dieback affected each monitoring site to varying degrees, however the LP control and enclosure treatment areas, shown in Figures 4 and 5 respectively, were the most severely impacted, both being entirely devoid of vegetation.

The dieback was not unique to Assateague Island but rather occurred in many low salt marshes throughout the Mid-Atlantic region. Aside from coinciding with the aforementioned prolonged inundation period, its causes are not yet understood. Ranwell (1981) suggested that dense algal growth may have caused a decline in vascular plant species in *Spartina* marshes in England via increased nutrient loading caused by direct algal discharges into the bay system or by increased eutrophication of run off. This theory is consistent with what occurred on Assateague Island since in 2006, close inspection of the affected low salt marsh areas frequently revealed the presence of abundant mats of algae covering dead *S. alterniflora* stems. These algal mats appeared to have developed and remained over low salt marsh areas during the inundation event.

Figure 3. Lee's Peninsula Control treatment area after 2006 "sudden dieback" event.



Figure 4. Lee's Peninsula Enclosure treatment area after 2006 "sudden dieback" event.



Furthermore, Stevenson, et al (2007) found that during the fall of 2006 in a restored marsh site at Blackwater National Wildlife Refuge, nitrogen and phosphorous levels exceeded *S. alterniflora* plant requirements in marsh sediments. They also found sulfide levels in pore waters that are known to limit *S. alterniflora* nitrogen assimilation. This likely resulted from lower iron levels in pore waters, since low iron levels act to limit the site's ability to minimize sulfides. They hypothesize that sandy materials weighed down

the rhizomatous mat – aggravating subsidence and increasing water-logging which manifested itself in reduced oxygenation in the root zone and in increased soil sulfide concentrations.

Analyses revealed that the 2006 mean weights, from both grazed and exclosed treatment areas, were significantly lower than the corresponding means from all other years. Figure 3 also shows that exclosed treatment areas maintained significantly higher amounts of vegetation during the dieback event, demonstrating that horse grazing reduced the ability of Assateague Island's low marsh communities to tolerate this event.

During the analyses of the productivity data, the four study sites were also considered independently. Recall that during this study it has also been considered to be the most heavily impacted by horse grazing. The monitoring results support this by revealing a significant overall average reduction in total aboveground vegetation of 74.1%, Table 2. During each round of data collection the dry aerial vegetation weights for the NE consistently had the widest discrepancy between grazed and exclosed treatment areas. At the same time, the NE site exhibited the most consistent within treatment mean dry weight of aerial vegetation over time. Despite high levels grazing, the NE site has demonstrated a capacity to quickly recover as exemplified by the exclosure treatment area having reached levels of primary productivity on par with other, less heavily impacted, exclosure treatment areas.

The NE monitoring site also tolerated the effects of the 2006 dieback event better than any other site, producing the highest level of primary productivity in the exclosed treatment area and maintaining its level of productivity within the grazed treatment area at levels similar to those found during prior sampling rounds (Table 2). In addition to the NE's previously mentioned greater exposure to ocean tidal influences, this result may also be partly attributable to the geology of the NE monitoring site, which is adjacent to the shallow, narrow waters of Sinepuxent Bay, both to the south and west. During the 2006 dieback, prevailing winds were predominantly out of the north and northwest. Conceivably, these winds helped blow the water resulting from recent higher than predicted tides and excessive rain events off of this monitoring site to the south.

The LP monitoring site's overall average reduction in total aboveground vegetation of 23.5% was not significant. Recall that the LP monitoring site is located near Chincoteague Bay on a peninsula surrounded by two deepwater guts to the north and south. Land access to this site is only gained by passing through a long (>1 km) and narrow (<50m in some places) area of dense shrub habitats. The relative isolation of this site may act to limit horse access, resulting in an overall lower grazing frequency and intensity. This may explain the occurrence of higher productivity being found in the LP grazed, as opposed to exclosed, treatment area during 1994, Table 2.

Conversely, LP obviously experienced a significant decrease in productivity during 2006 in both exclosure and control treatment areas. It is important to observe that at this site exposure to long-term rest from horse grazing did not result in an improved ability for the

low salt marsh to resist the affects of the dieback. Possible reasons for this are discussed in the following section where *S. alterniflora* stem count results are presented.

Analyses of data from the HW monitoring site revealed a significant overall reduction in total aboveground vegetation of 33.9% attributable to horse grazing. This was at least partially the result of the established influence of horse grazing on the distribution and abundance of *S. alterniflora* and *D.spicata*, (Furbish 1990, Furbish, et al 1994) since both species are present at this site. Additional monitoring results, presented below, further support this conclusion..

The VA monitoring site experienced a significant overall 41.1% reduction in total aboveground vegetation that was attributable to horse herbivory (Table2). In 1994, vegetation sampling from the VA Exclosure treatment produced an average dry weight of 64.2 g/25 cm². This was by far the highest average productivity of any treatment area throughout the monitoring project. This occurred during the first round of sampling, however since then the levels of productivity at this site have been more in line with values from other sites. This result demonstrates that localized areas may experience periodic dramatic increases in productivity that may be caused by temporary changes in nutrient levels, only to later return to more typical productivity levels.

Spartina alterniflora Stem Density

The pooled 2006 *S. alterniflora* stem density was significantly lower than those from all other monitoring years, revealing that during this year a universal significant reduction in *S. alterniflora* stem density occurred.. A similar result was found when grazed sites were considered separately, however upon comparing *S. alterniflora* stem density from exclosed treatment areas, 2006 was only significantly less than 1997 and 2000, years during which the highest mean *S. alterniflora* stem densities were found (Table 3).

It is important to note that the NE exclosure site was the most productive treatment area during 2006 (Tables 2 and 3). Given the NE's proximity to the Ocean City inlet, and the relative narrowness of Sinepuxent Bay adjacent to the site, the NE was likely less susceptible to prolonged inundation caused by the excessive rain and wind blown tides that coincided with the 2006 dieback.

Stribling (1989) hypothesized that high horse grazing intensity experienced in low salt marsh areas on the North End of Assateague Island was the likely cause of *S. alterniflora*'s unique phenotypic expression of high stem density and short growth form in the North End portion of the island. Table 3 supports this hypothesis, revealing that the NE monitoring site has consistently had significantly higher stem densities, frequently having a mean stem density more than double that found at other monitoring sites.

Table 3. Mean number of *Spartina alterniflora* stems (#SA) per 25 cm² from treatment areas grazed by horses and exclosure treatment areas that were exposed to rest from horse grazing, along with the associated standard error (Std Error) by year (n=5 for NE, LP, HW and VA monitoring site estimates, n=20 for each All Site estimate).

Monitoring Site	Treatment	1994		1997		2000		2003		2006	
		# SA	Std Error	# SA	Std Error	# SA	Std Error	# SA	Std Error	# SA	Std Error
NE	Grazed	171.8	7.8	126.9	29.6	130.4	34.1	118.6	32.3	56.0	10.1
	Exclosure	230.7	13.1	209.2	16.8	244.1	14.3	154.2	4.9	100.6	8.2
LP	Grazed	54.3	2.7	95.6	19.8	75.8	13.6	56.4	3.2	0.0	0.0
	Exclosure	59.7	2.0	98.3	15.6	79.6	10.3	56.8	2.9	0.0	0.0
HW	Grazed	31.2	4.5	48.9	5.7	48.2	12.9	23.7	3.7	6.6	1.8
	Exclosure	49.1	3.6	69.1	14.0	60.4	7.3	38.4	7.4	43.2	5.4
VA	Grazed	50.0	3.3	69.4	11.1	58.3	8.2	55.5	8.9	18.7	3.8
	Exclosure	45.0	1.1	77.4	12.4	51.6	5.6	65.0	5.9	30.6	4.3
All Sites	Grazed	76.9	12.9	85.2	11.0	78.2	11.7	63.6	11.1	20.3	5.6
	Exclosure	96.2	18.1	113.5	14.6	108.9	18.6	78.6	10.6	43.6	8.7

Although the NE levels of primary productivity quickly recovered upon exposure to rest from horse grazing, the number of *S. alterniflora* stems per unit area in the exclosure treatment area has remained significantly higher than those of other treatment areas. At the same time, within the NE exclosure treatment area there has been a significant decline in the number of stems per unit area over time. This indicates that just as *S. alterniflora* stem density may increase in response to prolonged exposure to intense grazing pressures, it may similarly, gradually decrease after this grazing pressure is removed.

LP is also the only other site, besides the NE, to have exhibited a significant decline in *S. alterniflora* stem density, which occurred during the 2006 die-back (Table 3). The persistent northerly winds that blew elevated waters off of the NE site also tended to accumulate these waters over the LP monitoring site because of the immediately adjacent elevated shrub habitat to the south. Therefore, one hypothesis is that the LP monitoring site's observed dieback was strongly influenced by these prevailing winds which acted to maintain excessive amount of standing water over the site for a prolonged period.

Distichlis spicata Stem Density

Low salt marsh habitats throughout the mid-Atlantic region are characteristically species depauperate. During this monitoring project *Distichlis spicata*, *Salicornia maritima*, *Spartina patens*, and *Limonium carolinianum* have been encountered at sample locations. Of these only *D. spicata* has been encountered with any regularity, primarily only at one site, HW. Table 4 shows the number of *D. spicata* stems found during data collection throughout this project.

D. spicata stem density was not significantly different between grazed and exclosure treatment areas nor did it vary significantly over time. Not surprisingly however, *D. spicata* stem density was significantly higher at HW in comparison to other monitoring sites. At HW, *D. spicata*'s patchy distribution and its tendency to have high stem counts in those sample locations where it was encountered is reflected by the high standard error values shown in Table 4.

As was alluded to previously, a factor that has also been detrimental to the stability of the HW monitoring site is the increased abundance of *D. spicata*. *D. spicata*'s atypical tendency to occupy large patches of low salt marsh particularly at this site may be attributable to an increased competitive advantage over *S. alterniflora* due to the influence of horse herbivory as first presented by Furbish (1994).

According to this hypothesis, areas influenced by horse herbivory become less vegetated by *S. alterniflora* which in turn allows *D. spicata* (a non-preferred forage species) to establish itself in low salt marsh areas in the absence of prolonged inundation, which *D. spicata* does not tolerate. Conceivably, these conditions have resulted in the large patches of *D. spicata* in low salt marsh areas observed at the HW monitoring site. The effects of this process are significant for two reasons. First, this process cumulatively eliminates previously available foraging areas, causing horses to concentrate their foraging behavior in the remaining *S. alterniflora* dominated low salt marsh habitats. Second, low marsh areas that become occupied by *D. spicata* increase their vulnerability to suddenly becoming devegetated because *D. spicata* does not tolerate inundation as well as *S. alterniflora*. Although the HW results to date do support this theory, a more rigorous study designed specifically to test this hypothesis is needed to be conclusive.

Table 4. Mean number of *Distichlis spicata* stems (#DS) per 25 cm² from treatment areas grazed by horses and exclosure treatment areas that were exposed to rest from horse grazing, along with the associated standard error (Std Error) by year. n=5 transects per treatment with each transect value being the average of 5 randomly sampled 25cm² locations.

Monitoring Site	Treatment	1994		1997		2000		2003		2006	
		# DS	Std Error	# DS	Std Error	# DS	Std Error	# DS	Std Error	# DS	Std Error
NE	Grazed	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Exclosure	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LP	Grazed	21.8	5.5	8.0	1.3	0.0	0.0	0.0	0.0	0.0	0.0
	Exclosure	4.2	3.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HW	Grazed	39.6	2.8	54.4	16.7	68.0	14.4	39.6	9.9	31.3	8.7
	Exclosure	13.3	1.5	45.2	9.1	48.4	6.1	51.5	10.4	38.6	3.6
VA	Grazed	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Exclosure	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Furthermore, as was previously mentioned, the HW control treatment area has eroded since it was first established in the early 1990's. There is a large inland lagoon located near this treatment area to the east. Over time the western bank of this lagoon has gradually eroded to the point where today the lagoon itself now occupies a considerable portion (well over half) of what was the original 50m x 50m treatment area. The 2006 treatment area resizing (to 30m by 30m) helped remove some but not all of the eroded portion of this treatment area. This treatment area will likely continue to erode, converting vegetated low salt marsh habitat to open water and mudflats. As a result the utility of this site for the purposes of this monitoring program has been jeopardized. It is therefore recommended that a new HW control treatment area be established or that the site be abandoned for the purposes of this monitoring project.

The transition of the HW Control treatment area from low salt marsh to eroded mud flat and open water is expected to continue since much of the remaining vegetated area is occupied by *D. spicata*. Should a new control treatment area be established at this site, it

should be randomly relocated within the bounds of being in the near vicinity of the HW enclosure and yet outside the influence of the expanding lagoon.

Spartina alterniflora flowering stems

Table 5

Year	Mean number of <i>Spartina alterniflora</i> seed heads			
	per 1m ²		per 100 stems	
	Grazed	Exclosed	Grazed	Exclosed
1994	41.9	66.1	4.1	4.3
1997	22.4	19.0	1.8	1.4
2000	30.9	52.5	4.0	2.5
2003	26.7	67.4	3.4	4.4
2006	11.5	40.6	3.4	4.0
All Years	26.7	49.1	3.3	3.3

Horse grazing significantly reduced the overall number of *S. alterniflora* flowering stems (Table 5: values per 1m²). However the overall mean percent flowering *S. alterniflora* stems (Table 5: values per 100 stems) was roughly equivalent between treatment areas. This result indicates that horses do not

preferentially graze on *S. alterniflora* seed heads but rather that the existing horse grazing intensity during this monitoring program has been sufficient to significantly reduce the reproductive success of the low salt marsh's dominant grass species.

Percent Vegetative Cover

Total percent vegetative cover was not collected during 2000. Table 6 shows the summary mean percent cover data collection results. Overall vegetative cover was significantly lower in grazed treatment areas and has also declined significantly over the course of this monitoring program. These results are consistent with findings from the primary productivity analyses. However Table 6 reveals that the estimated percent vegetative cover fluctuated at each site so much that the level of fluctuation was often inconsistent with other monitoring results.

Table 6. Mean percent cover (Mn%Cov) by sampling year per monitoring site and grazing treatment category as well as across all sites. Standard errors (Std Error) are also shown for each estimate. (n=5 for NE, LP, HW and VA estimates, n=20 for each All Site estimate)

Monitoring Site	Treatment	1994		1997		2003		2006	
		Mn%Cov	Std Error	Mn%Cov	Std Error	Mn%Cov	Std Error	Mn%Cov	Std Error
NE	Grazed	59.4	2.1	28.6	6.3	25.0	7.7	31.4	7.1
	Exclosure	94.4	3.8	68.3	5.0	57.1	1.8	54.4	1.7
LP	Grazed	70.6	3.5	43.2	11.0	27.7	1.9	0.0	0.0
	Exclosure	64.5	5.3	67.6	9.5	38.0	1.7	0.0	0.0
HW	Grazed	58.8	3.4	17.3	5.4	9.8	2.8	16.0	6.0
	Exclosure	67.1	3.0	33.0	2.4	15.2	4.3	42.6	3.2
VA	Grazed	61.8	5.1	30.4	7.4	19.1	2.2	24.1	4.7
	Exclosure	75.9	3.2	42.3	8.4	25.7	2.2	39.9	3.8
All Sites	Grazed	62.6	4.0	29.9	8.3	20.4	5.1	17.9	7.2
	Exclosure	75.5	6.5	52.8	9.5	34.0	7.6	34.2	9.7

Consider for example the All Sites values presented in Table 2 with those in Table 6. Once again Table 2 reveals that the mean total dry weight of clipped vegetation across all monitoring sites remained relatively consistent between 1994 and 2003 before decreasing significantly in both grazed and exclosed treatment areas in 2006. By comparison, Table 6 reveals that there was a significant decline in overall vegetative cover across All Sites

between 1994 and 1997 and then overall vegetative cover declined significantly again between 1997 and 2003 while finally, the 2003 and 2006 total vegetative cover did not differ from one another. Further complicating the interpretation of these results are additional contradictory results found during the analyses of vegetative cover data from individual monitoring sites.

Although total percent vegetative cover and total dry weight of sampled vegetation should logically be strongly correlated, since they both reflect low salt marsh productivity, primarily of one species, *S. alterniflora*, a correlation analysis revealed that they are only marginally positively correlated (Pearson's correlation value 0.673). The above results and the relatively weak correlation of these two vegetative parameters may be attributable to observer bias.

Many different observers have collected data throughout this monitoring program. Ultimately observer turnover may have contributed to the high variation found in the percent vegetative cover data, despite considerable effort during each round of data collection to maintain consistency. Therefore, the true condition of treatment area vegetation during each round of sampling is arguably most accurately reflected by the mean weight of dried vegetation. This is because unlike vegetative cover estimates, the mean weight of dried vegetation is the product of methodical data collection where little opportunity for observer bias exists.

Line-intercept or pin-contact sampling methods may be better suited to maintaining consistency between data collection periods and observers. Such methods could easily be adapted to the monitoring program's existing sampling scheme. Prior to any continued vegetative cover sampling, consideration should be given towards adopting a new sampling technique. In particular, the line intercept or pin-contact techniques mentioned above may improve data quality by reducing opportunities for observer bias to occur.

Conclusions

Throughout this project existing levels of horse grazing at ASIS significantly reduced primary productivity in low salt marsh habitats. The severity of the reduction varied between treatment sites as well as over time and depended on the intensity and frequency of exposure to horse grazing.

Horse grazing primarily affected *S. alterniflora* in these habitats. Productivity of individual plants were impacted by both grazing and trampling affects. The reproductive success of *S. alterniflora* was also reduced through non-preferential seed consumption. The cumulative affects of grazing on productivity during this monitoring project also reduced the low salt marsh's ability to tolerate and withstand other stressors such as the documented dieback that occurred during 2006.

Horse removal allowed low salt marsh areas to significantly recover from the effects of long term exposure to horse grazing. The improved condition of these the low salt marsh areas allowed them to better tolerate other environmental stressors as exemplified by the

condition of exclosed treatment areas in three out of the four study sites during the 2006 dieback event.

The response of the fourth treatment area, LP, demonstrated that other factors are equally capable of detrimentally affecting ASIS's low salt marsh areas regardless of existing levels of horse grazing. These other factors can devastate expansive areas of low salt marsh and can also affect their long term health. Attempting to understand what contributing factors may have caused the 2006 dieback event should be incorporated into any continued long-term, low salt marsh monitoring program.

Overall stem densities of *S. alterniflora* significantly declined during 2006. This decline occurred in both grazed and exclosed treatment areas. The definitive cause of this decline remains uncertain however it coincided with a period of prolonged submersion of Assateague Island's marshes. Possible causes include the deleterious influence of macro algae which developed in abundance during the event and associated alterations in nutrient pathways as proposed by Ranwell (1981) and Stevensen, et al (2007).

Furbish (1990) concluded that the chemical/physical conditions and vegetation types in Assateague Island's low salt marshes were indicative of a mature, low-production marsh. At the time she stated that under the existing conditions, a net loss of marsh habitats was to be expected. The development of this project's treatment areas supports this conclusion. Past dune construction activities at ASIS interrupted the cross-island movement of sediments which has influenced the declining health of Assateague Island's marshes. Beginning in the 1970's, the NPS stopped maintaining its constructed dunes throughout most of the Maryland end of Assateague Island. Since then the constructed dunes have been allowed to degrade in the interest of restoring natural barrier island ecosystem processes. In concert with management of the ASIS horse population at sustainable levels, it is believed that once restored, the periodic cross-island movement of water deposited sediments will help revitalize Assateague Island's low marsh habitats, allowing them to increase in area, elevation and productivity.

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