

Effects of Grazing by Feral Horses, Clipping, Trampling, and Burning on a Georgia Salt Marsh

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ABSTRACT: Responses of *Spartina alterniflora* marsh to combinations of feral horse grazing, clipping, simulated trampling, and a late winter burn were studied on Cumberland Island National Seashore, Georgia. Replicated 200-m² plots were established and sampled bimonthly from July 1983 to November 1984. Clipping and trampling each reduced peak aboveground biomass by 20% in 1983 and 50% (clipping) and 55% (trampling) in 1984. A March burn reduced peak aboveground biomass by 35% in 1984. Trampling and burning each reduced net aboveground primary production (NAPP) by 35%, but clipping did not reduce NAPP. Standing stocks of live rhizomes were correlated with aboveground biomass and were reduced with experimental treatments. Abundance of the periwinkle snail (*Littorina irrorata*) was also reduced. Horse grazing had a substantial impact on standing stocks and NAPP of *Spartina*, but grazing was not uniform throughout the marsh. Moderately grazed plots had NAPP reduced by 25% compared to ungrazed plots. Heavily grazed plots had extremely low NAPP, and aboveground *Spartina* never exceeded 40 g m⁻² dry mass compared to 360 g m⁻² within exclosures.

Introduction

Cumberland Island is inhabited by free-ranging feral horses (*Equus caballus*) that frequently graze in the salt marshes (Lenarz 1983). Vertebrate herbivory in salt marshes may alter the structure of the vegetation (Chabreck 1968; Shanholtzer 1974), reduce net aboveground primary production (Reimold et al. 1975), reduce standing stocks of belowground biomass (Smith and Odum 1981), result in a network of paths (Howell 1984), or reduce invertebrate populations (Reimold et al. 1975). In mixed species marshes, relative species abundance or successional patterns may be changed (Ranwell 1961; Bakker 1978, 1985; Dijkema 1984; Jensen 1985). In the presence of ungulates, plant regeneration may be slow because of trampling (Chabreck 1968; Jensen 1985). Fire in wetlands may also influence herbivory (Smith and Kadlec 1985). Although burning is a common wildlife management practice (e.g., White et al. 1978), few studies have been conducted to determine the effect of fire on salt marshes (Kozlowski and Ahlgren 1974; Smith and Kadlec 1985). Burning is not common in Atlantic coastal marshes, but some *Spartina* spp. marshes are occasionally ignited by lightning fires (Davison 1984).

The objectives of this study were (1) to determine the effects of feral horse grazing on the salt marsh; (2) to determine the effects of experimental perturbations (clipping, trampling and burning) on

above- and belowground *Spartina alterniflora* tissues, sediment macroorganic matter, and abundance of the periwinkle snail, *Littorina irrorata*; and (3) to determine the effects of the disturbances on net aboveground primary production.

Methods

STUDY AREA

The study site was located on Cumberland Island, Camden County, Georgia (30°48'N, 81°26'W). The 9,404 ha island extends 25 km from north to south and at its widest point measures 9 km. The geology, soils, water resources, vegetation, and fauna of Cumberland have been described by Hillestad et al. (1975). The island is generally of low relief (5-8 m above sea level) except for dune areas that may reach elevations of 18 m. Major plant communities are typical for barrier islands of the Georgia coast (Johnson et al. 1974). The tidal land on the mainland side of the island is characterized by smooth cordgrass, *Spartina alterniflora*. The upper margin of the marsh grades into a grass-forb community composed primarily of glass wort (*Salicornia virginica*), salt grass (*Distichlis spicata*) and occasional stands of black needle rush (*Juncus roemerianus*). This border community comprises 1.8% of the island and is grazed by horses. Tides in the marsh are semidiurnal with ranges of 2-3 m during neap and spring tides.

EXPERIMENTAL DESIGN

Study plots were located in a large salt marsh on the southern end of the island in homogeneous stands of short (<1 m) *Spartina alterniflora*. Experimental treatments were replicated at two sites approximately 600 m apart, referred to as north and south (Fig. 1). Moderate and high intensities of horse grazing were studied, along with all combinations of clipping, trampling, and burning. All treatments except ferrous grazing were contained within exclosures designed to exclude only horses, allowing free movement of other animals (such as raccoons) and tidal material. Exclosures were 1 m longer and wider than study plots, providing a 1-m buffer zone around each plot. They were constructed using 2.4-m fiberglass stakes set approximately 2 m apart and strung with three rows of 20 gauge barbed wire.

Clipping was done bimonthly from July 1983 to November 1984 with a weed trimmer that cut the grass to a height of 10 to 15 cm, simulating a moderate intensity of horse grazing. Grass clippings were left on the marsh surface and were lost in a few days through tidal action. Vestergaard (1985) found no difference in the response of marsh vegetation to mowing with and without clippings left on the marsh.

Trampling was simulated biweekly for the duration of the study. Using a trowel, holes to a depth of 15–20 cm were created at 1-m intervals in the plots. These were designed to simulate effects of the horse hooves, which cut through the root mat. The treatment was repeated during alternate weeks to prevent rhizome regrowth and sedimentation in the trample holes.

Two experimental burns took place 11 March 1984. Conditions for burning were selected such that tidal amplitude was low (midway between full moon and new moon) and low tide occurred during midday, to allow for maximum drying. Due to the effect of previous horse grazing, stalks of standing dead were not spaced closely enough to carry the fire, and additional fuel was spread over the site to provide fuel continuity. A bale of hay was added to each 100 m² burned. The burn was more intense in the south plots, where grazing was light, than in the north plots, which were more heavily grazed. Only aboveground vegetation was consumed by fire; roots and rhizomes were not burned.

Sampling was done bimonthly, beginning in July 1983 and continuing through November 1984. A lengthwise 9-m transect was randomly established in each study plot with the constraint that no area was sampled twice. Samples were then collected systematically at 3-m intervals. Aboveground vegetation was harvested to within 2 cm of the marsh

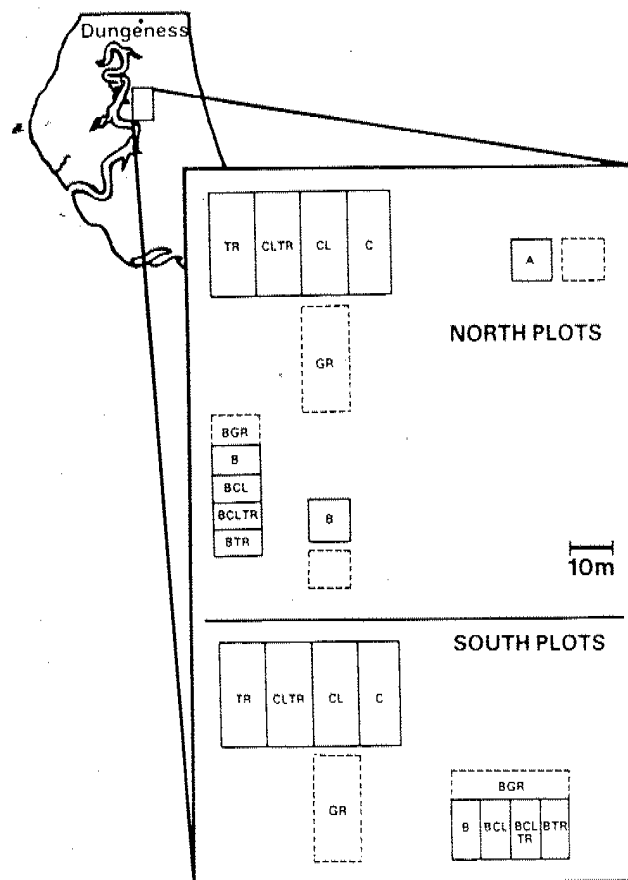


Fig. 1. Arrangement of study plots, Cumberland Island, Georgia. Exclosures A and B are in heavily grazed areas; other plots are in moderately grazed areas. North and south plots are approximately 600 m apart.

surface from eight circular 0.25-m² clip plots along each transect. The number of live periwinkle snails (*Littorina irrorata*) on each of the eight clip plots was recorded (Smalley 1959). Belowground material was randomly sampled on four of the clip plots using a coring device (10 cm diameter) made from PVC pipe. Cores were cut in the field to a depth of 10 cm.

Aerial vegetation was washed, sorted into live and dead, and dried to constant mass at 60 °C. Cores were washed over a 1-mm mesh sieve. Live rhizomes were separated visually from the material retained on the sieve (Schubauer and Hopkinson 1984) and removed. Rhizomes were dried at 60 °C to a constant mass. Macroorganic matter that did not pass through the 1-mm sieve was retained; it consisted mostly of live and dead *Spartina* roots. Because of insufficient drying oven space, macroorganic matter samples were frozen in the field, then dried to constant mass in Athens, Georgia.

Net aboveground primary production (NAPP)

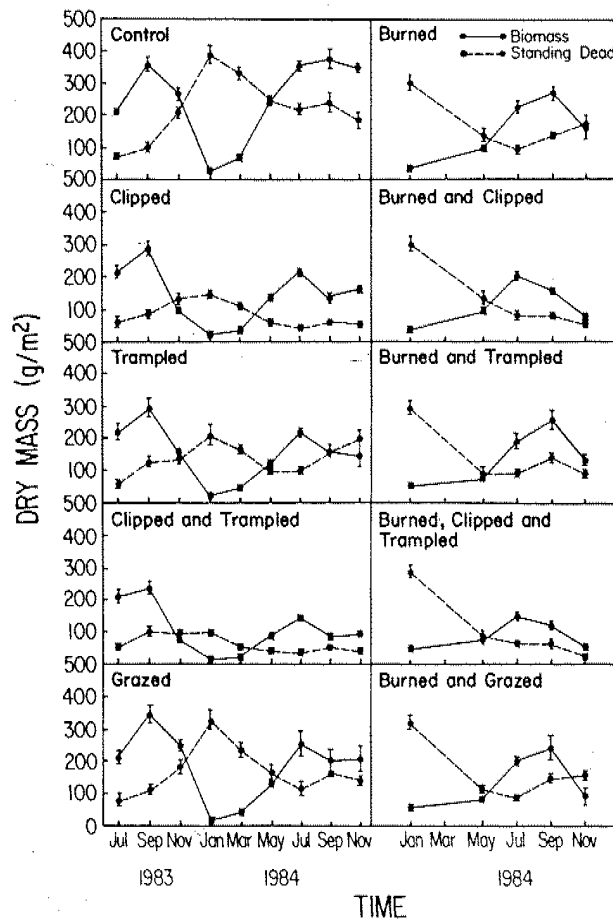


Fig. 2. Mean standing stock of aboveground *Spartina* by treatment (± 1 standard error, $n = 16$).

was calculated for each study plot following Smalley (1959). This method underestimates productivity because it does not account for decomposition or herbivory losses (Linthurst and Reimold 1978; Shew et al. 1981; Dickerman et al. 1986),

but it was adequate to compare relative rates of productivity among treatments. NAPP was calculated so that losses due to clipping were included. The difference between vegetation remaining after each clipping treatment and that present at the beginning of the next sampling period was used to compute NAPP for each interval.

Standing stock data (live biomass, standing dead, live rhizomes, macroorganic matter) and snail counts were tested for normality using the SAS univariate procedure and by plotting means versus variances for each variable. Data were normally distributed ($p < 0.01$, Kolmogorov D statistic); thus, parametric statistical procedures were used. Analyses were done using SAS (SAS Institute 1982). Standard analyses of variance were performed on data for each sampling date.

Results

Standing stocks of live *Spartina* biomass reached annual maxima during late summer (Fig. 2) and peak standing dead occurred in early winter, as is typical (Gallagher et al. 1980; Giurgevich and Dunn 1982). All experimental perturbations caused a decline in the peak value, with the clipping + trampling combinations causing the greatest decline. Effects due to clipping alone and trampling alone were similar. Moderately intense horse grazing reduced peak biomass by 29% in 1984. Mean standing stocks of aboveground biomass and standing dead generally decreased from control to most disturbed (Table 1).

Location of plots (north and south sites), treatment, and the interaction between location and treatment contributed significantly to the variance in standing stocks of aboveground vegetation (two-way ANOVA, $p < 0.05$). Transformations (log, square root) of data did not remove the interaction effect, indicating the two sites in some way responded differently to the treatments. When differences

TABLE 1. Mean aboveground *Spartina* and live rhizomes by treatment, July 1984.

Live biomass (g m^{-2} , $n = 16$)									
C	GR	TR	BR	BRCL	CL	BRGR	BRTR	BRCLTR	CLTR
344	266	237	232	216	210	198	195	158	135
Standing dead (g m^{-2} , $n = 16$)									
C	GR	TR	BR	BRTR	BRCL	BRGR	BRCLTR	CL	CLTR
210	120	106	103	100	96	88	72	47	42
Live rhizomes (g m^{-2} to 10 cm depth; $n = 8$)									
C	BRCL	BR	GR	CL	BRCLTR	BRTR	TR	BRGR	CLTR
523	425	361	315	280	247	240	239	235	231

* Notation: C = control; CL = clipped; TR = trampled; BR = burned; GR = grazed; combinations of treatments use the same notation.

Underlined means do not differ ($p > 0.05$, Bonferroni *t*-tests).

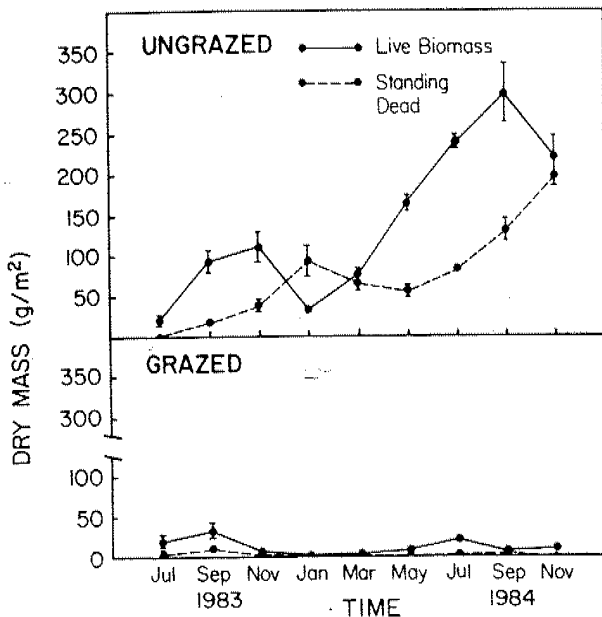


Fig. 3. Aboveground *Spartina* in heavily grazed and ungrazed study plots (± 1 standard error, $n = 16$).

were observed, the south plots had more aboveground vegetation than the north (Table 2). The southern site also received little grazing throughout the study, and live biomass in the south grazed plot at times exceeded the control. To eliminate this effect, analyses of variance were run excluding plots grazed by horses; only experimental treatments and controls were included. This eliminated interactions in five of the nine sampling periods. Remaining interactions may be due to differences in plant morphology resulting from different levels of prior grazing intensity.

In the heavily grazed area, aboveground vegetation differed between grazed plots and exclosures A and B (Fig. 3). Peak live biomass in grazed plots was 40 g m^{-2} dry mass, while peak biomass in ungrazed plots was 360 g m^{-2} dry mass. Two-way ANOVA indicated significant treatment effects ($p < 0.001$ for all dates) and occasionally significant location effects. Exclosure A had more biomass or standing dead than exclosure B whenever a location effect was observed. There was a significant interaction effect (treatment*location) for live biomass only in November 1983 and for standing dead in four of nine sampling periods.

Clipping had little effect on NAPP, whereas trampling reduced NAPP (Fig. 4). The combined clipping + trampling treatment resulted in low NAPP, which was less than observed in naturally grazed plots. Moderate grazing reduced NAPP by 25%. All burned plots had lower NAPP in 1984 than did their respective unburned plots (Fig. 4).

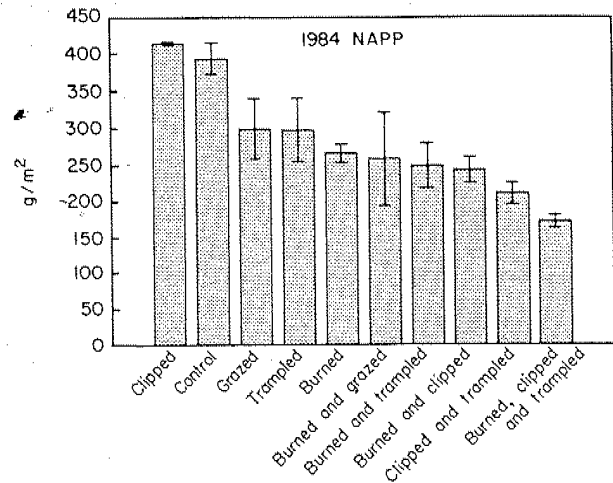


Fig. 4. Net aboveground primary production of *Spartina* in 1984 by treatment (± 1 standard error, $n = 2$).

The effects of clipping, trampling and grazing were similar within burned and unburned treatments.

Control plots generally contained higher live rhizome biomass than moderately perturbed plots (i.e., grazed, clipped or trampled) and the clipped + trampled plots had the lowest standing stocks of live rhizomes (Fig. 5). Burning appeared to have little effect. Two-way ANOVA again showed significant effects due to location, treatment, and the interaction between location and treatment. The south plots almost always had higher standing stocks of live rhizomes than the north plots. Live rhizomes were significantly correlated with aboveground biomass ($r = 0.43$, $p = 0.0001$).

Densities of the salt marsh periwinkle (*Littorina irrorata*) were highly variable among experimental plots. The south plots contained higher densities of snails than did the north plots; in fact, densities

TABLE 2. Mean biomass and standing dead *Spartina* among treatments by location (g m^{-2} dry mass).

Date	Biomass*		Standing Dead**	
	North	South	North	South
July 83	180	258*	49	92*
September 83	267	322*	88	128*
November 83	167	178*	134	177*
January 84	41	27*	221	281*
March 84	50	48	169	183*
May 84	118	123	92	153*
July 84	217	221	88	108*
September 84	204	255*	123	122
November 84	113	159*	110	133*

* Indicates that the north and south means differ ($p < 0.05$, Bonferroni *t*-tests).

** Data for 1983 and March 1984 include the 5 unburned treatments with 8 samples per treatment ($n = 40$); all other sample dates include all 10 treatments ($n = 80$).

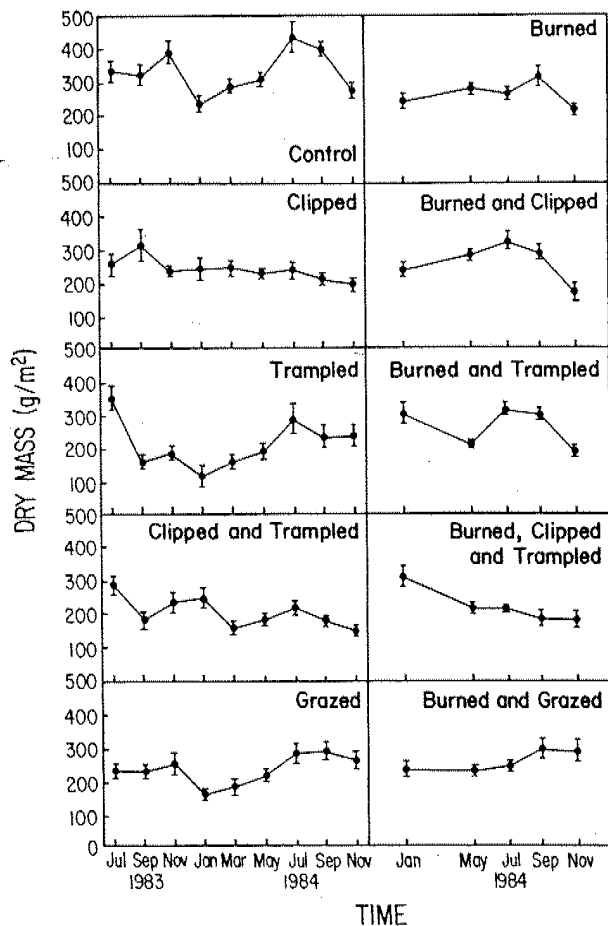


Fig. 5. Mean dry mass of live rhizomes of *Spartina alterniflora* in the top 10 cm of sediment by treatment (± 1 standard error, $n = 8$).

were too low in the north for treatment effects to be observed. Snails on the south plots responded to perturbations, but only during the second growing season. The trend was similar to that seen in the aboveground vegetation. Within both burned and unburned areas, control and grazed plots had the most snails while clipped + trampled had the fewest (Table 3). Burned plots in general had fewer snails than unburned plots.

On average, sediment macroorganic matter retained on a 1-mm sieve did not exhibit a consistent response to experimental treatments. Values ranged from 120 to 200 g m^{-2} dry mass to a depth of 10 cm. Although two-way ANOVA indicated variation due to treatment for eight of the nine sampling periods ($p < 0.05$), there was considerable overlap among treatment means. Sediment macroorganic matter was not correlated with rhizomes ($r = 0.032$, $p = 0.46$) or aboveground biomass ($r = -0.038$, $p = 0.37$).

TABLE 3. Density of *Littorina irrorata* by treatment, south plots, 1984 (no. m^{-2} (std. dev.)).

	May	July	September	November
Unburned				
C*	126.4 (51.6)	146.0 (24.8)	186.4 (38.4)	127.6 (28.4)
CL	60.8 (21.6)	62.0 (44.0)	172.4 (35.6)	134.0 (40.8)
CLTR	24.8 (13.6)	72.8 (28.8)	74.4 (19.6)	63.6 (27.6)
TR	154.4 (40.8)	89.6 (22.0)	108.8 (40.4)	76.0 (32.0)
GR	157.6 (40.8)	142.0 (50.4)	161.6 (32.8)	122.0 (32.4)
Burned				
C	76.0 (13.2)	66.4 (40.4)	76.8 (28.4)	67.2 (30.4)
CL	76.0 (13.2)	69.6 (33.2)	89.6 (32.8)	44.8 (18.0)
CLTR	36.0 (15.2)	64.4 (42.4)	54.0 (28.4)	18.4 (16.8)
TR	36.0 (15.2)	46.0 (21.2)	40.4 (17.2)	42.4 (23.6)
GR	104.0 (28.8)	52.4 (19.2)	82.4 (47.6)	75.2 (27.2)

* Notation: C = control; CL = clipped; TR = trampled; BR = burned; GR = grazed; combinations of treatments use the same notation.

Discussion

Response of the ecosystem varied by treatment and by component. The response of grasses to clipping is well-known (Cook et al. 1958; Detling et al. 1979; McNaughton 1979; Reuss 1984), and it is not surprising that clipping did not reduce NAPP. Trampling, however, had a significant independent effect, and when combined with clipping, NAPP was reduced. Other studies have also reported significant effects due to trampling (Edmond 1964; Brown and Evans 1973; Charles 1979; Jensen 1985). When soil moisture is high, as in salt marshes, trampling often leads to loss of soil structure (Jensen 1985). This study suggests that trampling may be the more destructive component of grazing by large ungulates in the marsh.

Burning seemed to be qualitatively different from both clipping and trampling. Plots which were burned exhibited a more dense growth of smaller *Spartina* stems compared to unburned plots. Plots which were clipped or trampled chronically did not show this morphological change to fine dense growth. The lower NAPP is similar to the observations of Smith and Kadlec (1985), who found lower standing stocks in burned *Typha latifolia* and *Distichlis spicata*. In contrast, winter or early spring burns in marshes on the Gulf Coast resulted in increases in aboveground productivity (Whipple and White 1977; Hackney and de la Cruz 1983.) Gulf Coast marshes are subject to less tidal influence than Atlantic marshes, and there may be less export of nutrients released by burning on the Gulf Coast.

Horses have a strong impact on large portions of the high marsh. Horse grazing pressure is not uniform, but varies from intense near the upland to light further into the marsh. The upland area of marsh is by far the area most severely affected.

Some heavily grazed areas are already withstanding very intense grazing pressures. In these areas, standing stocks of live biomass never exceed 40 g m⁻² dry mass. Heavily grazed marshes may be more susceptible to erosion and storm damage, since accretion of sediment in marshes is a function of the density of grasses present to trap particles (Gleason et al. 1979).

Although the marsh is a grassland, the interactions between vertebrate grazers and *Spartina* may be different than those observed in other grasslands. The muddy substrate may be more susceptible to deleterious effects of trampling, which have a significant effect on NAPP. Intense grazing by horses may alter the detrital food web, indirectly affect other consumer populations, or change the export/import of organic matter from the marsh. With the presence of large herbivores, grazing should play an important role in the trophic dynamics of marshes.

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