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## Effects of Feral Horse Grazing, Clipping, Trampling and a Late Winter Burn on a Salt Marsh, Cumberland Island National Seashore, Georgia

CPSU Technical Report 23

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May 1986

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# Effects of Feral Horse Grazing, Clipping, Trampling and a Late Winter Burn on a Salt Marsh, Cumberland Island National Seashore, Georgia

*Monica Goigel Turner, Institute of Ecology, University of Georgia, Athens GA 30602.* CPSU Technical Report 23. University of Georgia, Athens. 43 pp. May 1986

## Abstract

Cumberland Island National Seashore, Georgia, is inhabited by free-ranging feral horses that heavily graze the upland portions of the island's salt marshes. The interaction between horses and the marsh formed the basis of a broader study in which the effects of grazing, clipping, trampling and a late winter burn were studied in a *Spartina alterniflora* marsh. These disturbances were applied both singly and in combination in replicated experimental plots and studied from July 1983 through November 1984. A simulation model of carbon flow in the salt marsh was also developed to explore potential effects of increased grazing pressure.

Clipping and trampling each reduced peak biomass by 20% in 1983 and 50-55% in 1984; burning reduced peak biomass by 35%. Trampling and burning each reduced net aboveground primary production (NAPP) by about 35%, while clipping did not reduce NAPP. Belowground standing stocks of live rhizomes were also reduced with disturbance, but sediment microorganic matter showed no significant trend. Abundance of the periwinkle snail (*Littorina irrorata*) decreased with the clipping treatments during the second growing season.

Responses to combined disturbances were tested to determine whether or not the effects of single disturbances could be added to obtain the combined effect. Whenever combinations were nonadditive, the effect of the combined disturbances was less than predicted, based on the disturbances acting alone. The observation that disturbances may combine in nonadditive ways may be an important consideration in the management of disturbance-prone ecosystems.

Horses had a strong impact on the marsh. In heavily grazed areas, aboveground vegetation was reduced by up to 98% compared to ungrazed areas. Grazing was most intense along upland portions of the marsh, but results from the simulation model and 1985 monitoring data suggest that grazing impacts may spread further into the marsh, unless feeding preferences change. Trampling appeared to be the more deleterious component of feral horse grazing in the salt marsh, rather than biomass removal. Preferential grazing on burned areas was not observed. The data and simulation model suggest a carrying capacity of 45-73 horses on Cumberland Island, based on their effects on the marshes. Recovery of the high marsh will not occur until the horse population declines, either naturally or through management actions.

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## Introduction

When Cumberland Island was designated a national seashore in 1972, it was inhabited by 3 species of free-ranging feral animals: pigs (*Sus scrofa*), cattle (*Bos taurus*) and horses (*Equus caballus*). Cattle are now mostly restricted to private lands, and a large proportion of the pig population has been removed to the mainland. The National Park Service has not attempted to manage or remove the feral horse population. Previous studies indicate that the population may be increasing at a rate of 5% per year (Lenarz 1983, Ambrose et al. 1983, Finley 1986) and in 1983 there was a minimum of 154 horses on the island (Ambrose et al. 1983).

The primary habitats used by the horses on CUIS include the salt marsh, grasslands, foredunes and interdune meadows. Lenarz (1983) reports 51.7% of his observations of horse grazing occurred in the marsh. The salt marsh community encompasses 34.1% of the island and occurs throughout the tidal land on the mainland side of the island between the upland and the tidal creeks, rivers and sounds. It is characterized by a dominant plant, smooth cordgrass (*Spartina alterniflora*). Exotic species, including feral animals, have been shown to have significant effects in numerous ecosystems (i.e. Sanchez 1974, Bratton 1975, Petrides 1975, Howe and Bratton 1976, Rudge and Campbell 1977). Thus, the horses could have a significant impact of the island's salt marshes.

The interaction between the horses and the marsh formed the basis of a broader study of multiple disturbances including clipping, trampling and a late winter burn. The objectives of the study were:

(1) To determine the effect of feral horse grazing on the salt marsh;

(2) To determine the effects of clipping, trampling and burning on the marsh;

(3) To determine whether the multiple disturbances were additive;

(4) To estimate a carrying capacity of horses based on the data and a simulation model.

## Methods

Study plots were located in a large salt marsh on the southern end of the island, approximately 2 km south of Dungeness (Figure 1). Replicated series of 10 x 20 m unburned experimental plots were established approximately 600 m apart; burned plots were smaller in size, 7 x 10 m, because of difficulties encountered in trying to burn a larger area. These 2 sets of replicates are referred to as the north and south series, denoting their relative locations on the marsh. Experimental treatments are shown in Table 1.

Exclosures were designed to exclude only horses. One set was erected in July 1983, and the second set in March 1984, following the experimental burn. They were constructed using 2.4 m fiberglass stakes, set approximately 2 m apart and strung with 3 rows of 20 gauge barbed wire. Exclosures were 1 m longer than study plots, providing a buffer zone around the plots. Each exclosure contained 4 study plots. Two additional 10 x 10 m exclosures were also erected on the high marsh in very heavily grazed sites and paired with plots which remained under heavy grazing pressure.

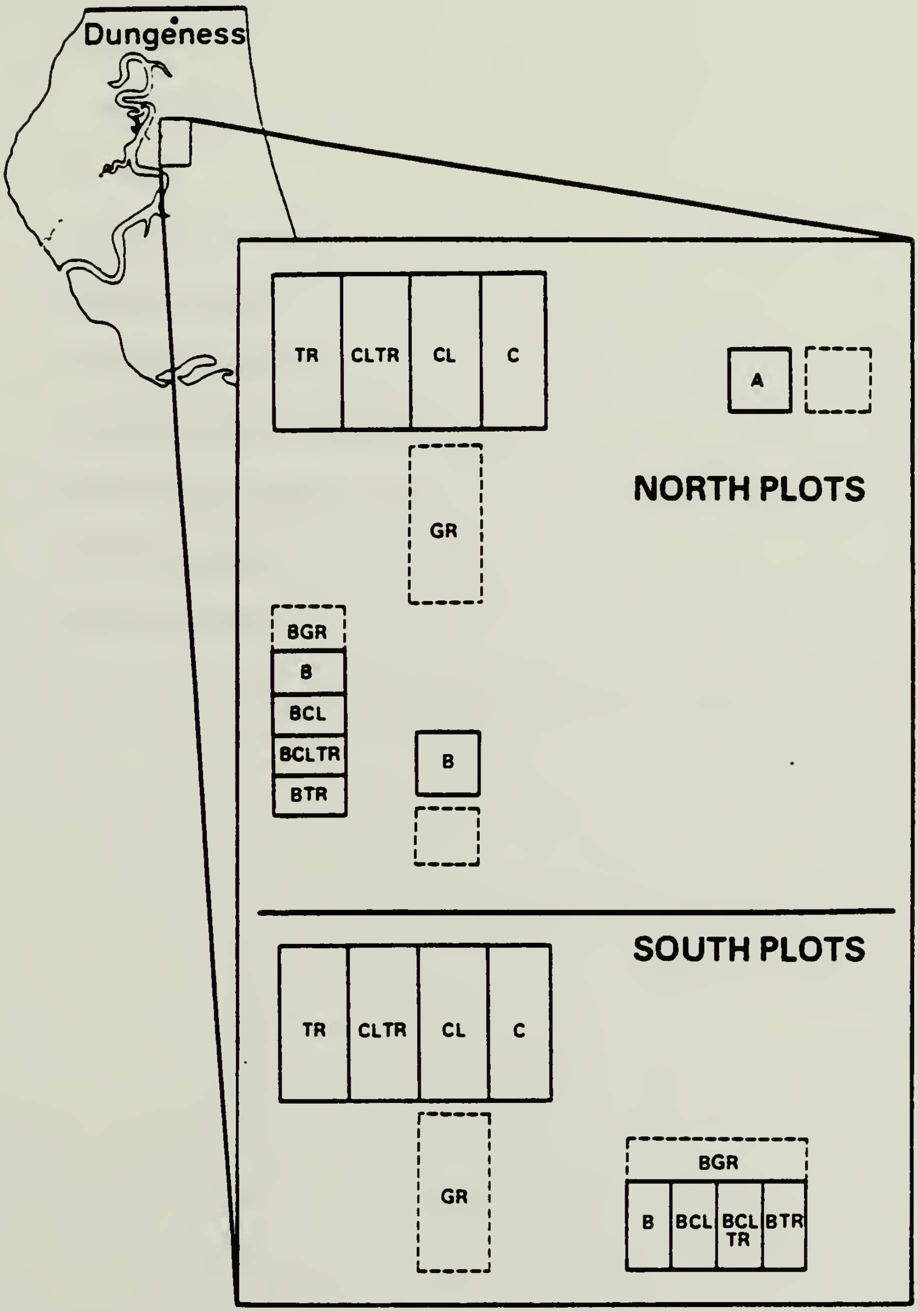



FIGURE 1. Location of study plots, Cumberland Island, Georgia

TABLE 1. List of experimental treatments.

| |
|---|
| Ungrazed control |
| Clipped |
| Trampled |
| Burned |
| Clipped+trampled |
| Burned+clipped |
| Burned+trampled |
| Burned+clipped+trampled |
| Moderately grazed |
| Heavily grazed |
| Burned+grazed |

The clipping perturbation was done bimonthly from July 1983 to November 1984 with a weed trimmer that cut the grass to a height of 10-15 cm. Trampling was simulated biweekly for the duration of the study. Using a trowel, holes to a depth of 15-20 cm were created and maintained at 1 m intervals in the study plots. The experimental burns took place 11 March 1984, and clipping and trampling treatments were subsequently applied on the burned areas.

Sampling was conducted bimonthly from July 1983 to November 1984 and included aerial vegetation, belowground live rhizomes and macroorganic matter, and abundance of *Littorina irrorata*. Sampling design and techniques are described elsewhere (Turner 1985). Aerial vegetation in grazed and ungrazed plots only was sampled again in September 1985.

To estimate a carrying capacity of horses based on their effects on the salt marsh, it was necessary to determine the area of marsh that was accessible to the horses. The upland portions of the marshes are bounded by tidal creeks that horses do not readily cross. This analysis was done using 1983 color infrared aerial photographs (1:24,000) and a Bausch and Lomb Zoom Transfer Scope. Area was determined by planimetry.

## Results

### Effects of Grazing

The data indicate that horses are having a strong effect on the salt marsh. Substantial differences in live and dead *Spartina* were found between the grazed and ungrazed plots in the heavily grazed area (Figure 2). Grazing caused a reduction of up to 98% of the aboveground vegetation. However, the intensity of horse grazing pressure varied in the marsh, as indicated by the differences between the north and south plots (Figure 3). In 1984, peak live

Figure 2. Standing stocks of live and dead aboveground *Spartina alterniflora* in grazed and ungrazed plots in a heavily grazed area of the marsh (mean $\pm$ 1 SE, n=4).

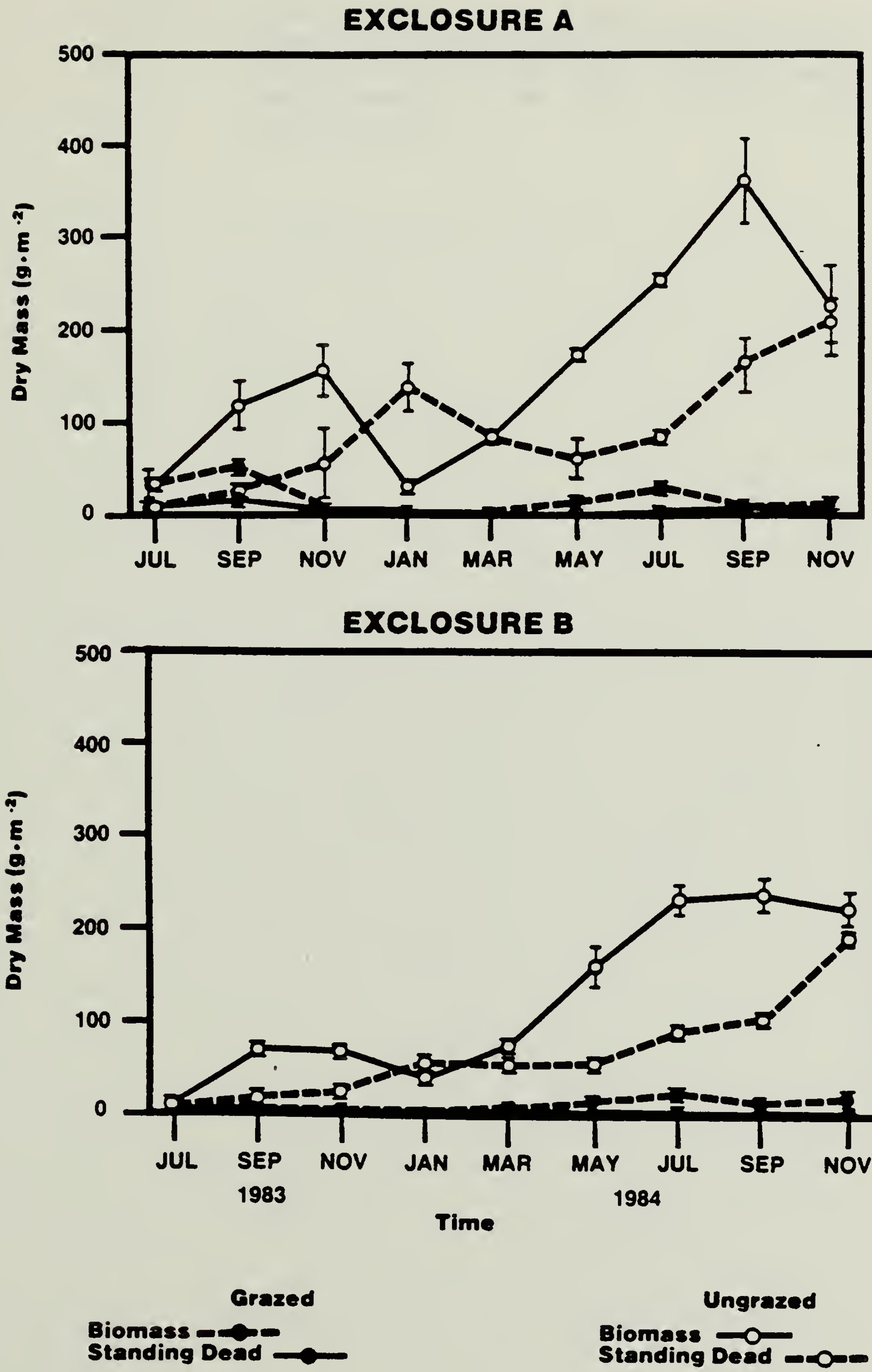
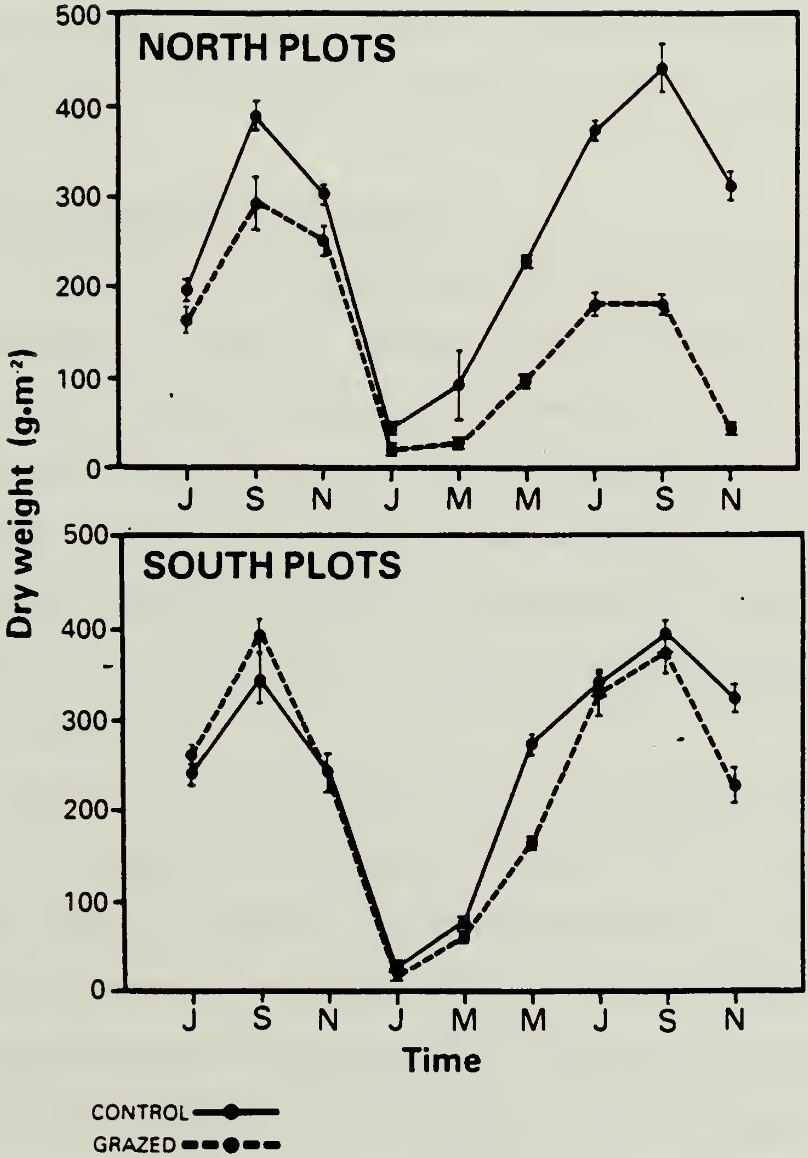

EXCLOSURE A
500
400
300
200
100
0
Dry Mass (g·m⁻²)
JUL
SEP
NOV
JAN
MAR
MAY
JUL
SEP
NOV
EXCLOSURE B
500
400
300
200
100
0
Dry Mass (g·m⁻²)
JUL
SEP
NOV
JAN
MAR
MAY
JUL
SEP
NOV
1983
1984
Time
Grazed
Biomass
Standing Dead
Ungrazed
Biomass
Standing Dead

Figure 3. Standing stock of live *Spartina alterniflora* in the grazed and ungrazed plots of the north and south replicate (mean $\pm$ 1 SE, n=8). Note the north plots were moderately grazed while the south plots were lightly grazed.


NORTH PLOTS
SOUTH PLOTS
Dry weight (g·m⁻²)
500
400
300
200
100
0
J S N J M M J S N
Time
CONTROL
GRAZED

vegetation in the north grazed plot was about 50% that of the control, whereas in the south replicate it was not significantly different from the control.

Peak biomass in grazed and ungrazed plots (Table 2) indicates that the effects of horse grazing in the marsh increased from 1983-1985. Between 1984 and 1985, the north replicate shifted from moderately to heavily grazed, and the south replicate went from lightly to moderately grazed. In the area of marsh closest to the uplands, biomass was consistently reduced by 96-98%.

## Effects of Experimental Disturbances

The effects of all experimental treatments on the aboveground *Spartina* are presented in Figure 4. Clipping and trampling each reduced the vegetation by approximately 20% in 1983 and 50% in 1984; the combined clipping+trampling disturbance reduced the vegetation by 40% in 1983 and 70% in 1984. Burning alone reduced aboveground vegetation, and further reductions were observed when additional disturbances were applied to the burned areas. However, there was no indication that horses grazed preferentially on burned sites.

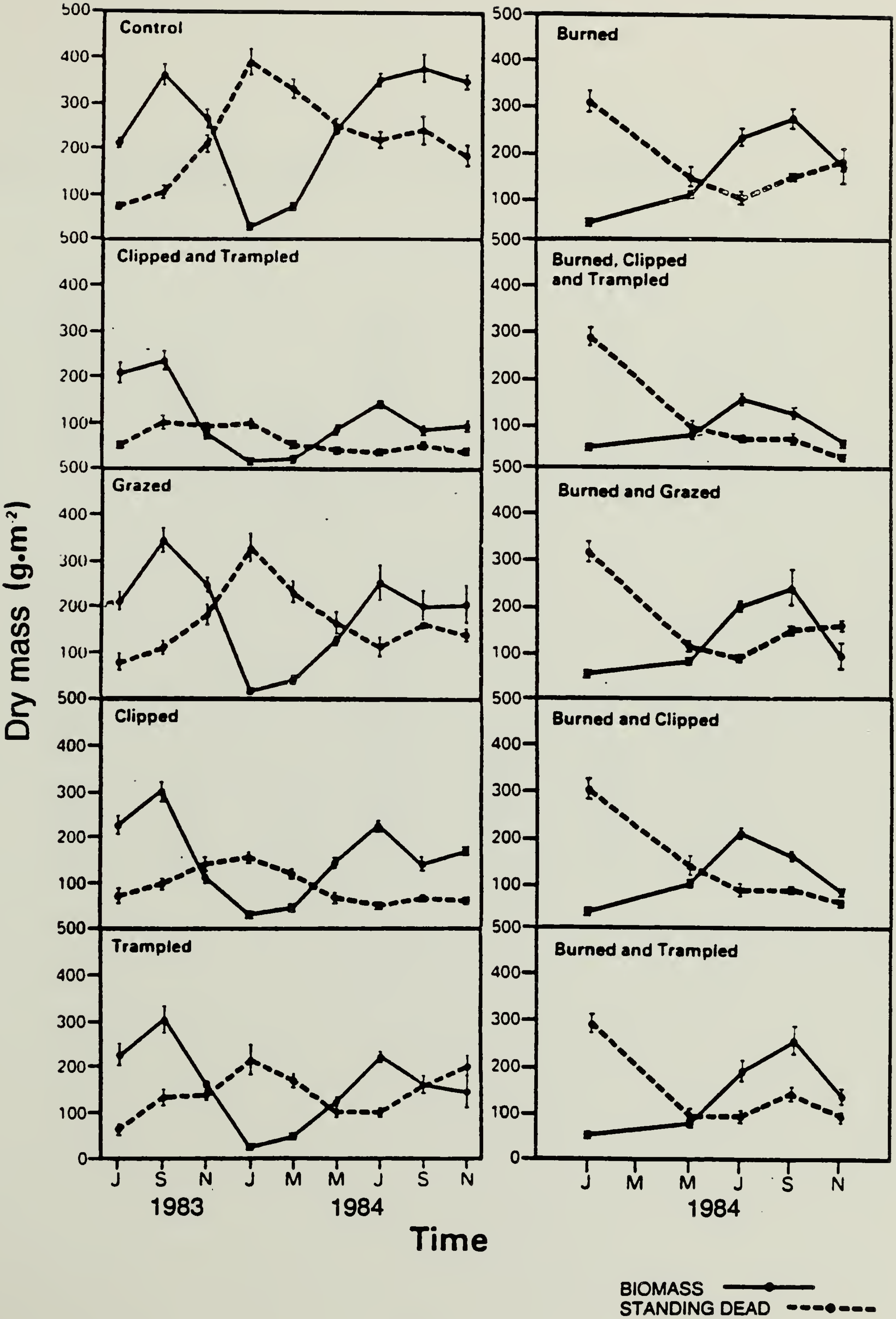
The effects of the disturbances on net aboveground primary production, or NAPP, (Figure 5) were slightly different from the effects on standing stocks. NAPP is a measure of how much plant material is actually produced in a year, as opposed to how much is present at any one time (standing stock). The main difference in effects was that clipping did not reduce NAPP compared to the control plots. In other words, although less biomass was present on the clipped plots at any one time, the same amount of biomass was produced during the year as if they were not cut. In contrast, plots that were trampled had 40% less aboveground production that the controls. This suggests that trampling by the horses may have a more severe effect on the

TABLE 2. Peak biomass of live *Spartina alterniflora* in grazed and ungrazed plots, Cumberland Island, Georgia.

| | UNGRAZED | | GRAZED | BIOMASS REMOVED BY HORSES |
|---|---|---|---|---|
| Exclosure A | | | | |
| 1983 | 120[1] | | 52 | 57% |
| 1984 | 364 | | 9 | 98% |
| 1985 | 528 | | 8 | 98% |
| Exclosure B | | | | |
| 1983 | 68 | | 14 | 79% |
| 1984 | 232 | | 7 | 97% |
| 1985 | 140 | | 5 | 96% |
| North Replicate | | | | |
| 1983 | 388 | | 292 | 25% |
| 1984 | 440 | | 180 | 60% |
| 1985 | 472 | | 28 | 94% |
| South Replicate | | | | |
| 1983 | 344 | ns | 382 | 0% |
| 1984 | 382 | ns | 372 | 0% |
| 1985 | 472 | | 228 | 52% |

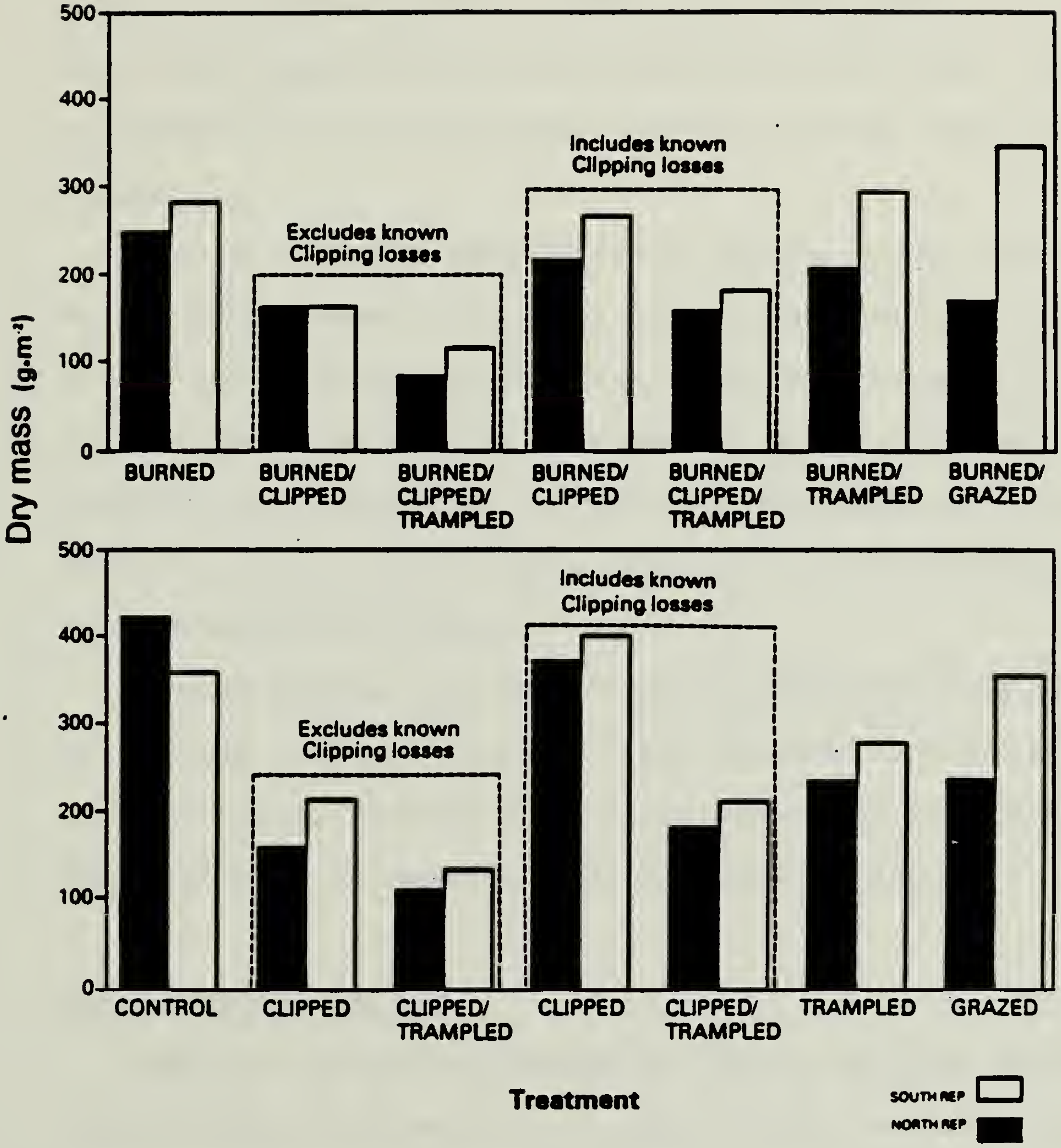
[1]All units are dry weight ($g/m^2$). Grazed and ungrazed are significantly different ($n=8$, $p<.05$) except where indicated by ns.

Figure 4. Standing stock of live and dead *Spartina alterniflora* for all experimental treatments (mean $\pm$ 1 SE, n=16).



Control
Burned
Clipped and Trampled
Burned, Clipped and Trampled
Grazed
Burned and Grazed
Clipped
Burned and Clipped
Trampled
Burned and Trampled
Dry mass (g·m⁻²)
J S N J M M J S N
1983 1984
J M M J S N
1984
Time
BIOMASS
STANDING DEAD

Figure 5. Net aboveground primary production of *Spartina alterniflora* in 1984.


Dry mass (g·m⁻²)
Includes known Clipping losses
Excludes known Clipping losses
BURNED
BURNED/ CLIPPED
BURNED/ CLIPPED/ TRAMPLED
BURNED/ CLIPPED
BURNED/ CLIPPED/ TRAMPLED
BURNED/ TRAMPLED
BURNED/ GRAZED
CONTROL
CLIPPED
CLIPPED/ TRAMPLED
CLIPPED
CLIPPED/ TRAMPLED
TRAMPLED
GRAZED
Treatment
SOUTH REP
NORTH REP

marsh vegetation than the removal of biomass. Plots that were burned all had less NAPP than their unburned equivalents.

Standing stocks of live Spartina rhizomes are presented in Figure 6. There was a consistent pattern of control plots having significantly higher live rhizome biomass than moderately perturbed plots (i.e. grazed, clipped, or trampled) and the clipped+trampled plots had the least amount of live rhizomes.

Densities of the salt marsh periwinkle (Littorina irrorata) were highly variable among experimental plots. The south replicates had higher densities of these snails than did the north plots; in fact, densities were too low on the latter for treatment effects to be observed. Snails on the south plots responded to the disturbances, but only during the second growing season (Table 3). Control plots and grazed plots had the most snails, while clipped+trampled had the fewest.

Macroinvertebrates in the sediment were also monitored for the duration of the study, but populations were highly variable and no trends were observed. Macroorganic matter in the sediment and nutrient concentrations in Spartina were also not responsive to the experimental treatments.

### Tests for Additive Responses

Responses to combined disturbances were tested to determine whether the effects of single disturbances could be added to obtain the combined effect, or whether the disturbances were not additive. Clipping and trampling, when combined, had additive effects. However, burning with either clipping or trampling exhibited nonadditive effects. Whenever combinations were nonadditive, the effect of the combined disturbances was less than predicted based on the disturbances acting alone. This was probably due to a change in the growth form of plants on the burned plots. The regrowth was extremely dense

Figure 6. Standing stock of live rhizomes of Spartina alterniflora for all experimental treatments (mean ± 1 SE, n=8).

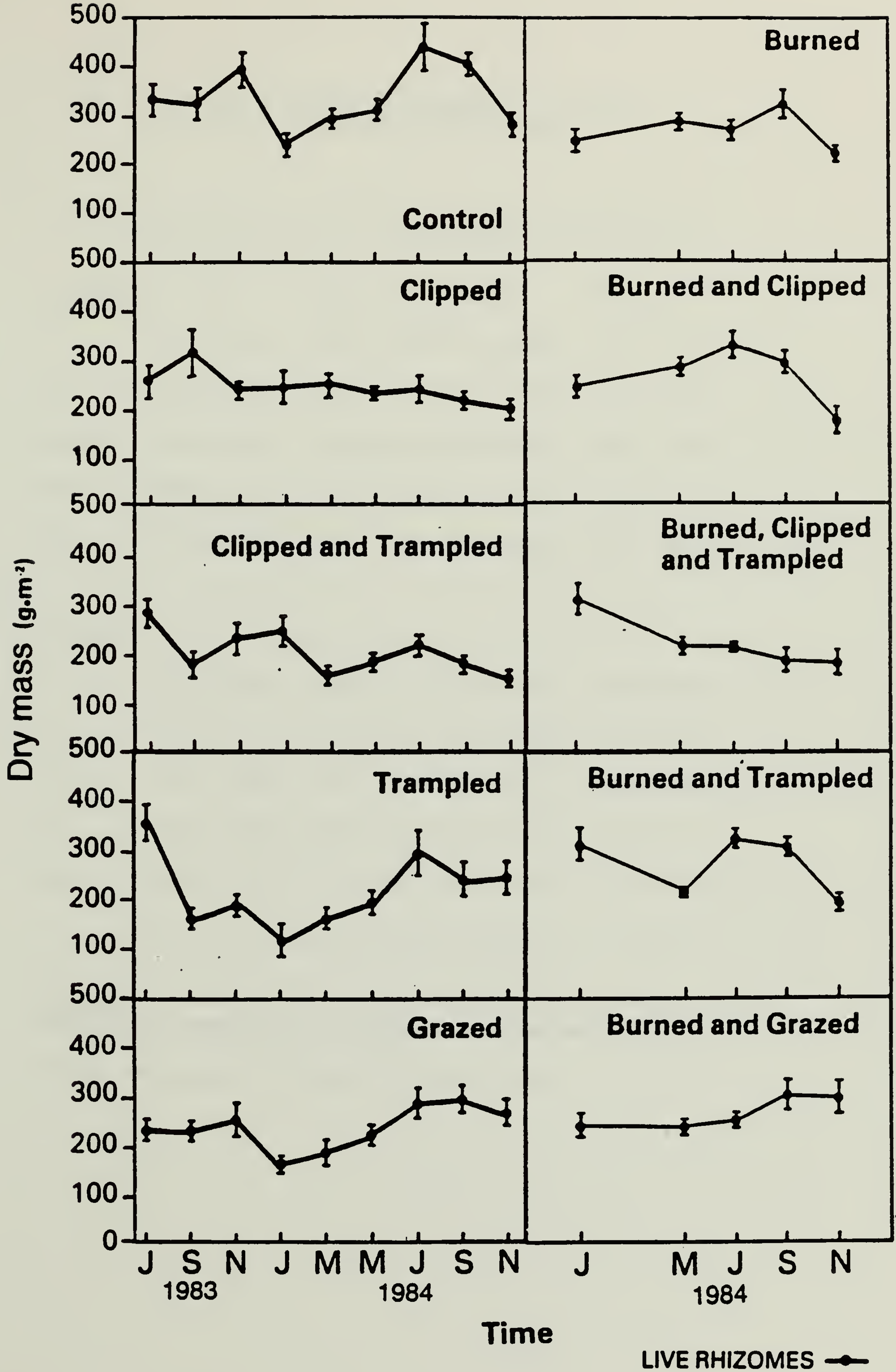

Control
Burned
Clipped
Burned and Clipped
Clipped and Trampled
Burned, Clipped and Trampled
Trampled
Burned and Trampled
Grazed
Burned and Grazed
Dry mass (g·m⁻²)
0
100
200
300
400
500
J S N J M M J S N
1983
1984
J M J S N
1984
Time
LIVE RHIZOMES

TABLE 3. Density of *Littorina irrorata* by treatment, south plots, Cumberland Island, 1984.

| Unburned | MAY | JUL | SEPT | NOV |
|---|---|---|---|---|
| C[1] | 31.6 (12.9) | 36.5 (6.2) | 46.6 (9.6) | 31.9 (7.1) |
| CL | 15.2 (5.4) | 15.5 (11.0) | 43.1 (8.9) | 33.5 (10.2) |
| CLTR | 6.2 (3.4) | 18.2 (7.2) | 18.6 (4.9) | 15.9 (6.9) |
| TR | 38.6 (10.2) | 22.4 (5.5) | 27.2 (10.1) | 19.0 (8.0) |
| GR | 39.4 (10.2) | 35.5 (12.6) | 40.4 (8.2) | 30.5 (8.1) |
| **Burned** | | | | |
| C | 19.0 (3.3) | 16.6 (10.1) | 19.2 (7.1) | 16.8 (7.6) |
| CL | 19.0 (3.3) | 17.4 (8.3) | 22.4 (8.2) | 11.2 (4.5) |
| CLTR | 9.0 (3.8) | 16.1 (10.6) | 13.5 (7.1) | 4.6 (4.2) |
| TR | 9.0 (3.8) | 11.5 (5.3) | 10.1 (4.3) | 10.6 (5.9) |
| GR | 26.0 (7.2) | 13.1 (4.8) | 20.6 (11.9) | 18.8 (6.8) |

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

[1]Units are number of snails/0.25 $m^2$ (sd); n=8.

and shorter than unburned plots. Clipping trimmed the plants to approximately 10 cm in height; with a short dense growth form, more biomass would remain than expected.

## Discussion

Horses are having a strong impact on a large portion of the high marsh. The data indicate that horse grazing pressure is not uniform throughout the marsh, but varies from very intense (near the upland) to light (out further into the marsh). The upland area of the marsh is by far the area most severely affected. Some heavily grazed areas are already withstanding very intense grazing pressures and standing stocks of live biomass never exceed 40 g dry weight per square meter. This is extremely low, even for short *Spartina*.

### *Implications of Horse Grazing on the Marsh*

Heavily grazed marshes may not be accreting sediment, and may be more susceptible to erosion and storm damage. Gleason et al. (1979) have shown that the accretion of sediment in a salt marsh is a function of the density of grasses present to trap particles. In sites which are heavily grazed, where peak biomass is 12 grams per square meter, the density of grasses is extremely low, and percent cover may be less than 20%. This may be an important consideration on Cumberland Island since the entire transitional area between the uplands and salt marsh is heavily grazed. This may render these areas susceptible to erosion or cutting by storm tides.

Species distribution may be altered by heavy grazing. Reimold et al. (1975) report a transition from Spartina to Salicornia with an intensive clipping treatment. Large expanses of Salicornia are apparent on the high marsh on Cumberland Island, and while this is a natural species, its range may have been extended by grazing. It is not a food source for the horses.

Horse grazing may be indirectly causing a decrease in grass productivity via fiddler crabs. Reimold et al. (1975) demonstrated that cattle grazing caused a decrease in the number of fiddler crabs, which have been shown to exert a positive influence on Spartina growth (Montague 1980). This is believed to result from their burrowing activities, which help to both drain and oxygenate the sediments. Fiddler crabs are also important sources of food for native wildlife, such as raccoons. Grazing also appears to affect the abundance of periwinkle snails in the marsh, which are important sources of food for other estuarine organisms.

Decreases in NAPP of Spartina resulting from grazing may indirectly affect the estuarine food web. Dissolved organic carbon (DOC) leached from Spartina leaves may add as much as 61 kg per ha per year to the estuarine water, and this material seems readily used by microbes (Gallagher et al. 1976). The bacterial biomass is then available to filter feeders and deposit feeders. Large decreases in Spartina NAPP may reduce the export of DOC, although this may vary seasonally.

Gallagher et al. (1980), in studying export dynamics of nutrients in the marsh, also report that the high marsh was often a nutrient exporter. As dead plants disappear from the marsh, they will become part of either the dissolved or particulate pools in the tidal waters; thus, the materials are exported from the community (Gallagher et al. 1980). This is another potential indirect pathway through which horse grazing may influence the overall estuarine environment by reducing macrophyte biomass.

The effects of trampling by feral ungulates can be substantial. Edmond (1964) found that trampling by sheep reduced production of 10 pasture grasses to between 9 and 77% of control. From a production point of view, all trampling damages pasture regardless of soil moisture, plant species or kind of animal (Brown and Evans 1973). When soil moisture is high, as in salt marshes, trampling often leads to loss of soil structure (Jensen 1985). If sediment is turned into a system of hollows and hummocks, roots may be poorly developed.

Although standing stocks of Spartina are reduced on the marsh with horse grazing, it is possible that moderate amounts of grazing will serve to increase NAPP. This effect was demonstrated in the clipping experiments in which losses due to clipping were known.

Thus, the potential effects of horse grazing are substantial and varied. Most of the high marsh is probably affected to some degree, and this represents the entire interface between the upland and wetland. Reimold et al. (1975) indicate that although grazing of ungulates is damaging to the marsh, it may be a reversible process with a turnaround time of approximately one year. Smith and Odum (1981) also report fairly quick responses to release from grazing pressure by geese.

The response of Spartina plants in control plots in this study lend support to these ideas, although a turnaround time of one year for the whole ecosystem may be a low estimate. A highly productive species, Spartina appears to be fairly resilient, rapidly recovering from disturbance. The existence of a refuge of biomass which is unavailable to grazers, in this case roots and rhizomes, may be the reason for this resilience (Noy-Meir 1975).

## Simulation Model

In simplest terms, a model is an abstract, simplified representation of the real world. It should incorporate the important functional attributes and relationships of the real system, although by definition it does not include all attributes and relationships. Simulation models have 3 primary uses: (1) to suggest new research questions or hypotheses; (2) to predict potential results of perturbations which may be expensive, difficult or destructive to real systems; and (3) to synthesize what is known about a system, aiding our conceptualization and study of complex systems. As part of this research, a model of the Cumberland salt marsh was developed to simulate current horse grazing pressure and to predict potential impacts of increased grazing. The structure of the model is shown in Figure 7, and it is fully described by Turner (1985).

Results of the model simulation of carbon in the ungrazed marsh are shown in Figure 8. The simulation agrees very closely with the observed field data, showing regular seasonal growth cycles with realistic amplitudes. The simulation values in grams carbon can be converted to dry weight by multiplying by 2.5 (1/0.4), since approximately 40% of dry plant matter is carbon. Results of 5 year simulations of different intensities of horse grazing are shown in Figure 9. There is a sharp demarcation between what appear to be tolerable levels of grazing (Figs. 9-a,b) and deleterious levels (Figs. 9-c,d), and the model suggests that there is a threshold level of biomass which must remain on the marsh to maintain its integrity. This threshold occurs at about 200 $g/m^2$ dry weight of live Spartina in the model (Figure 9-d), and the 1985 peak biomass data support this. The north plots were moderately grazed in 1984 and had a peak biomass of 180 $g/m^2$, but were heavily grazed in 1985, and peak biomass declined to only 28 $g/m^2$ (Table 2).

Figure 7. Diagram of the model simulating carbon flow in the salt marsh.

## SALT MARSH SIMULATION MODEL

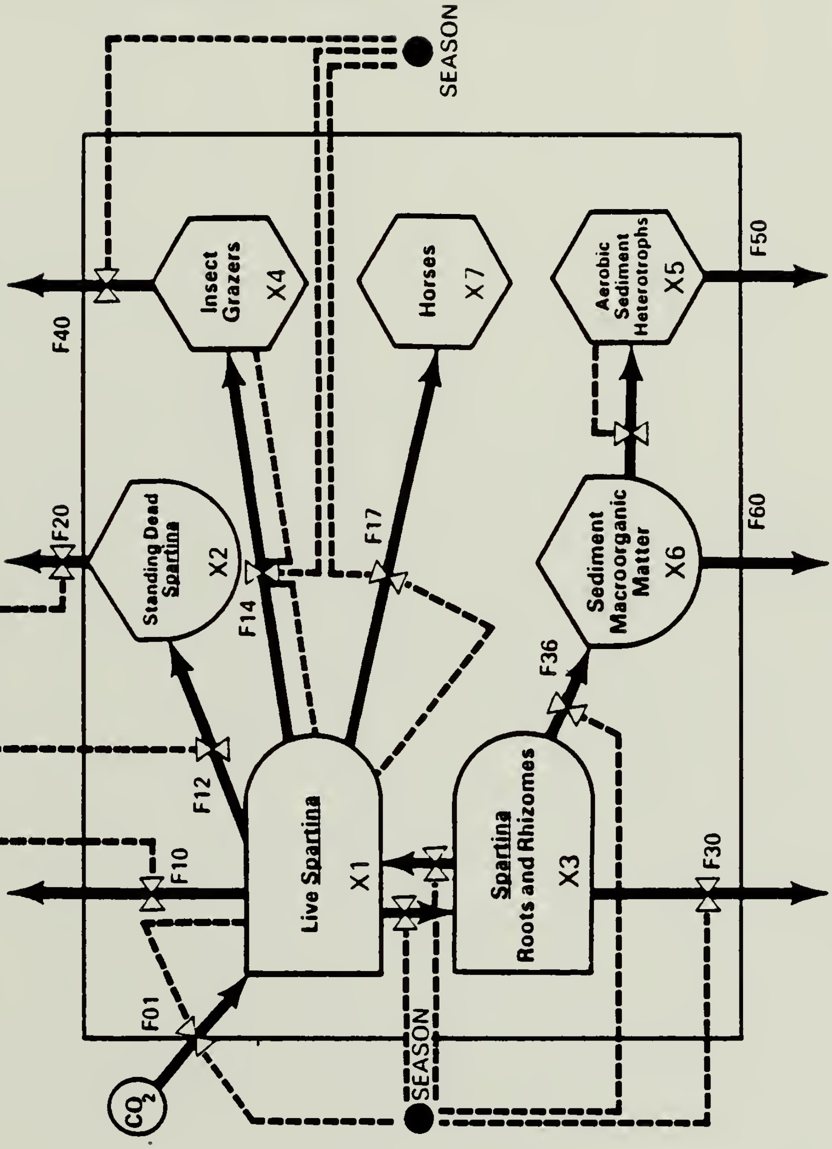


Figure 8. Simulation results for the ungrazed salt marsh. Figures a-c are 5 year simulations; Figure d is an expanded view of aboveground Spartina dynamics for 1 year.

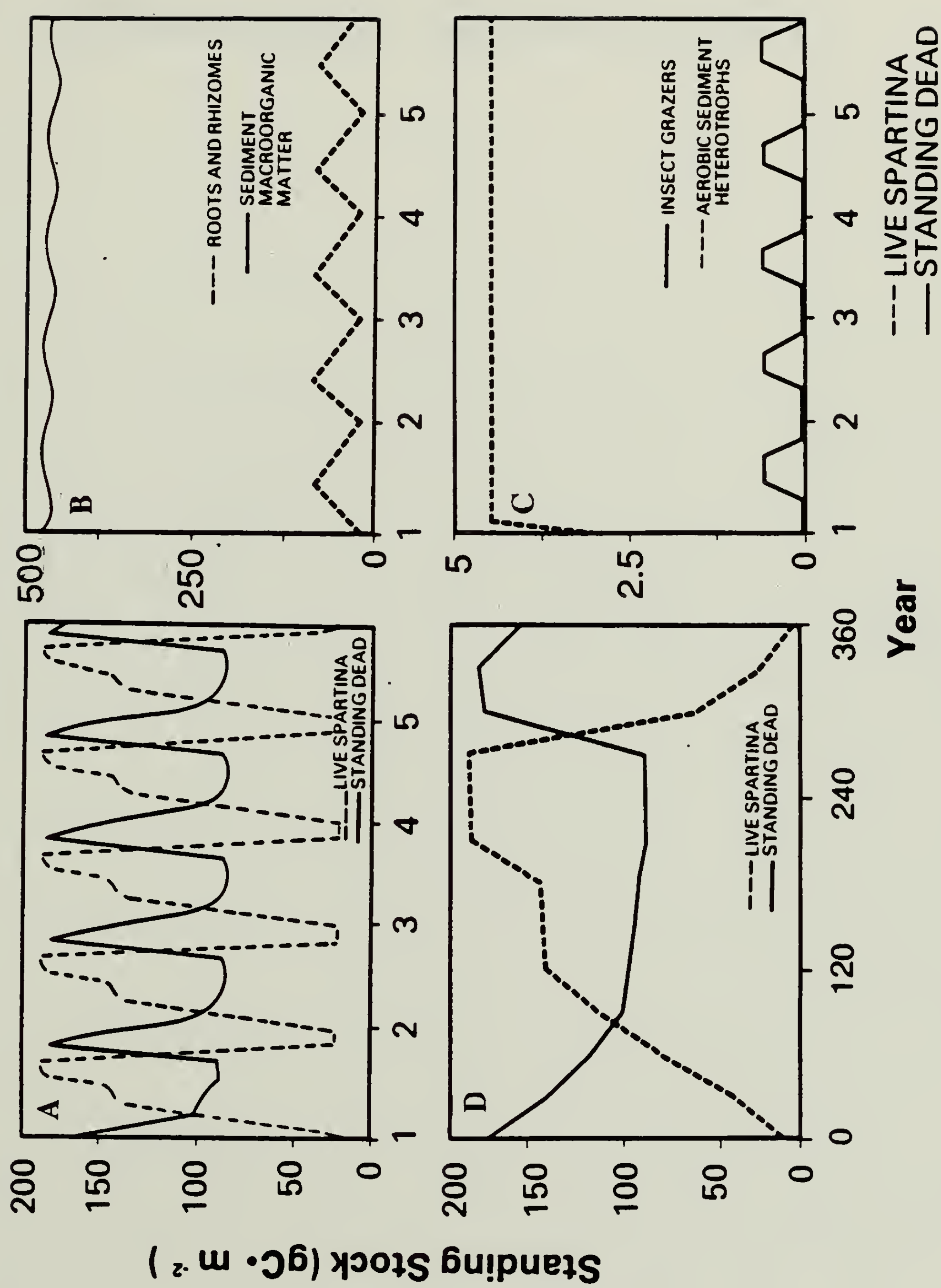
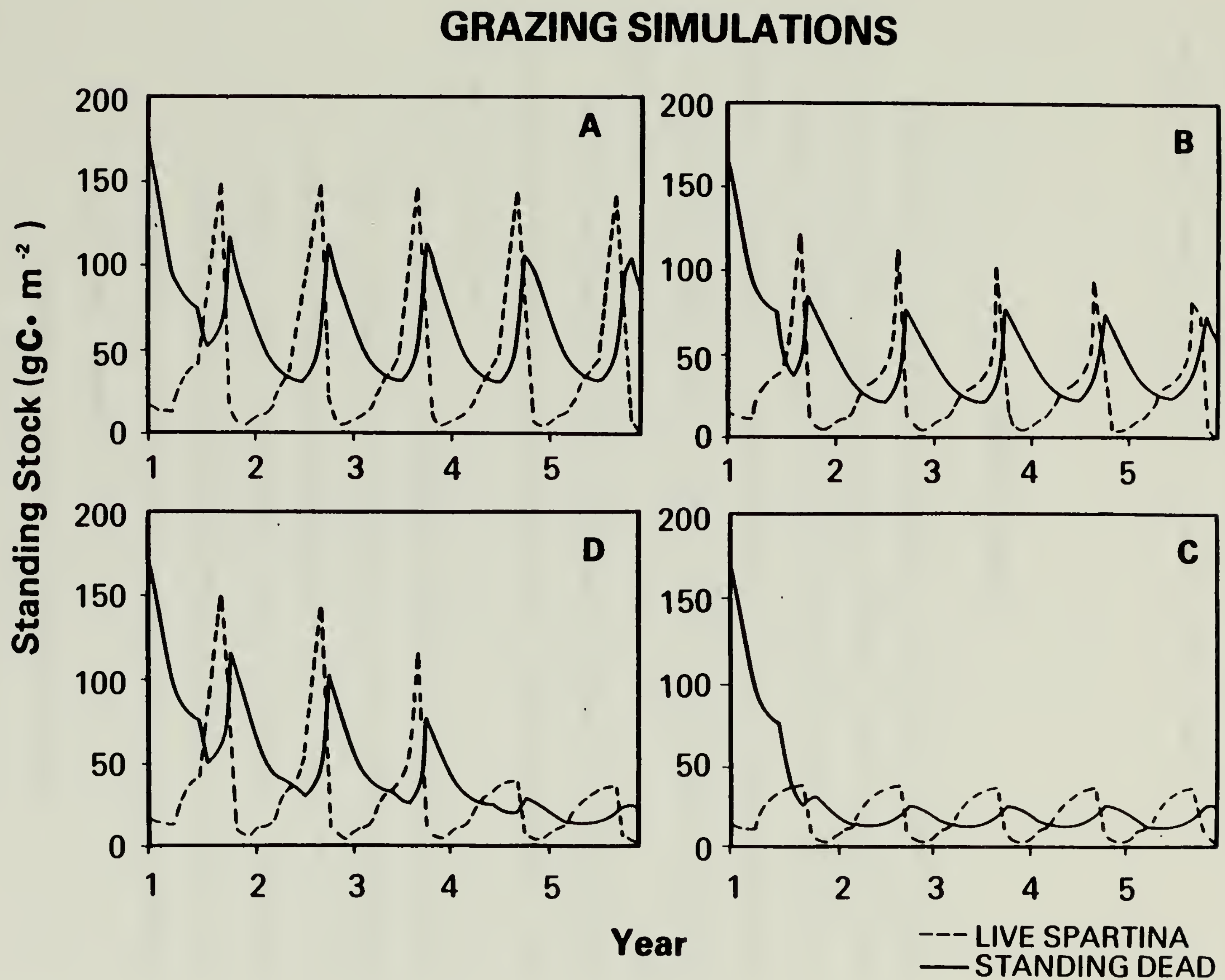

NOMINAL SIMULATION
Standing Stock (gC• m⁻²)
Year
A
B
C
D
LIVE SPARTINA
STANDING DEAD
ROOTS AND RHIZOMES
SEDIMENT MACROORGANIC MATTER
INSECT GRAZERS
AEROBIC SEDIMENT HETEROTROPHS
0
50
100
150
200
250
500
2.5
5
1
2
3
4
5
0
120
240
360

Figure 9. Results of 5 year grazing simulations showing dynamics of aboveground Spartina. Note threshold in Figure 9-d.


GRAZING SIMULATIONS
Standing Stock (gC• m⁻²)
A
B
C
D
200
150
100
50
0
1
2
3
4
5
Year
LIVE SPARTINA
STANDING DEAD

Invertebrate grazers and macroorganic matter were also affected by horse grazing in the model; invertebrate grazers decrease as Spartina decreases, and macroorganic matter is lost from the ecosystem as horse grazing intensifies. These results suggest the potential for severe effects on the remaining salt marsh ecosystem from increased grazing pressure.

## Carrying Capacity

The analysis of 1983 aerial photographs of Cumberland Island indicated that 411 ha of salt marsh were potentially available to the horse population. The population presently numbers 180 horses (Finley 1986) which represents a density of 0.44 horse/ha, or 1 horse for every 2.3 ha of marsh. Approximately 50% of this marsh area is already severely overgrazed (personal observation).

The data and simulation model can be used to estimate a carrying capacity of horses on Cumberland Island, based on their impacts on the marsh. This can be done as follows:

(1) First, the amount of Spartina consumed by a horse must be estimated. Although actual intake will vary among horses depending on their body size and physiological state, an average rate will be assumed. Based on standard horse nutritional requirements (Morrison 1949) and assuming horses at moderate work, daily diet requirements can be converted to approximately 20 kg dry forage per horse. Yearly ingestion is thus:

20 kg/day x 365 days = 7300 kg/year per horse

Since the horses do not obtain 100% of their forage from the marsh, the proportion of Spartina in their diet must be determined. Lenarz (1983) reports 52% of his observations of horse feeding occurred in the salt marsh. I will thus assume an average value of 50% Spartina in the diet, but will also examine greater (60%) and lower (40%) proportions of Spartina being consumed. The Spartina consumed annually per horse can be calculated as follows:

Spartina consumed per horse:

| | |
|---|---|
| more grazing | .60 x 7300 kg/year = 4380 kg/year Spartina |
| average | .50 x 7300 kg/year = 3650 kg/year Spartina |
| less grazing | .40 x 7300 kg/year = 2920 kg/year Spartina |

(2) Next, we must calculate the amount of Spartina available to the horses if the integrity of the marsh is to be maintained. In other words, how much biomass is available above the threshold indicated in the model?

The field data indicated a range of annual net aboveground primary production on the marsh from 3000-4250 kg/ha. The simulation model indicated a threshold level of 2700 kg/ha of Spartina below which the system could not be sustained. This suggests that a yearly loss to grazing of 300-1550 kg/ha might be tolerable, depending on location. Thus, on average, a loss of 800 kg/ha might be acceptable. Since trampling caused a decrease in vegetation equivalent to that of the actual biomass removal, only half of that 800 kg/ha should actually be consumed by the horses as forage. Thus, if we allow 400 kg/ha of Spartina to be grazed, we can calculate how much area of marsh is required to feed a horse:

Marsh area required per horse

| | | |
|---|---|---|
| more grazing | 4380 kg / 400 kg/ha = | 10.9 ha/horse |
| average grazing | 3650 kg / 400 kg/ha = | 9.1 ha/horse |
| less grazing | 2920 kg / 400 kg/ha = | 7.3 ha/horse |

(3) To calculate carrying capacities, the available marsh area must be divided by the area required per horse. Since there are potentially 411 ha of marsh available to the horses on Cumberland Island, we can determine the number of horses the marshes could reasonably support as follows:

| | | |
|---|---|---|
| more grazing | 411 ha / 10.9 ha/horse = | 37 horses |
| average grazing | 411 ha / 9.1 ha/horse = | 45 horses |
| less grazing | 411 ha / 7.3 ha/horse = | 56 horses |

The number of horses that could be supported by a portion of the island can also be determined similarly. For example, on the portion of the island south of Sea Camp, there are 92.5 ha of marsh available to horses. Substituting this 92.5 ha for the 411 ha used in the above calculations, the southern portion of the island could support:

| | |
|---|---|
| more grazing: | 8 horses |
| average grazing: | 10 horses |
| less grazing | 12 horses |

Thus, the following summary of the carrying capacity of horses can be prepared based on a tolerable level of grazing of 400 kg/ha:

| Spartina in diet | ha/horse | K, island | K, south end |
|---|---|---|---|
| 60% | 10.9 | 37 | 8 |
| 50% (avg) | 9.1 | 45 | 10 |
| 40% | 7.3 | 56 | 12 |

If the carrying capacities were calculated as above with more Spartina considered to be a tolerable loss to horse grazing, then the carrying capacity estimates would be higher. For example, by allowing 650 kg/ha of Spartina to be grazed instead of 400 kg/ha (which results in 1300 kg/ha of Spartina removed), the following estimates are obtained:

| Spartina in diet | ha/horse | K, whole island | K, south end |
|---|---|---|---|
| 60% | 6.74 | 61 | 13 |
| 50% (avg) | 5.61 | 73 | 16 |
| 40% | 4.49 | 91 | 20 |

These latter estimates are high, but provide some bounding for a maximum population size. Based on current grazing intensities, the carrying capacity of the island is probably between 45 and 73 horses.

It is important to note that these carrying capacity estimates are based solely on availability of and effects on the island's salt marshes. This is reasonable, since the marshes are the horses' prime feeding habitat. However, the effects of horses on other Cumberland Island habitats, such as the oak forest or interdune meadow, are not included in the model.

## Conclusions

The results indicate that horses significantly affect several components of the marsh, and that impacts may become more severe if the numbers of horses increase. For example, trampling effects, which are separate from biomass consumption, have been shown to depend upon stock densities and management practices (Ssemakula 1983). Based on the total marsh area available to horses and the potential implications for the marsh, management decisions regarding a tolerable population size should be made. This research suggests a carrying capacity of 45-73 horses for the island, based on present grazing intensities in the salt marshes.

Recovery from grazing on Cumberland Island would probably be most evident in the moderately grazed areas. The highest portions of the marsh would still receive considerable horse use due to proximity to the uplands and the relative firmness of the substrate. If horses were eliminated from certain portions of the island, for example the northern half, those marshes would probably show a rapid response to release from grazing. Horses could be maintained on the south end, reducing the amount of marsh impacted on the island, but the population should be reduced to 10-16 horses. Recovery of the marshes will not occur until the horse population declines, either naturally or through management actions.

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