Evaluation of the Ecological Role and Techniques for the Management of Tidal Marshes on the Mississippi and Alabama Gulf Coast

FINAL REPORT COVERING THE PERIOD
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Submitted by

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SUMMARY

SUMMARY

Because of the increasing human occupancy of coastal areas and the potential uses of some marsh vascular plants, varied and conflicting demands are being placed upon the coastal zone and its wetlands. Efforts must be made to find ways to manage coastal marshes without decreasing their productivity or damaging their value to man and wildlife. In this study, several management tools (i.e. fire, harvest and fertilization) were considered and their effects on the structure and productivity of the vegetation, on decomposition and microbial processes, and on the benthic faunal community were investigated.

Two marsh communities each in St. Louis Bay, Mississippi and Dauphin Island, Alabama were utilized during 1977 and 1978 to evaluate the effect of fire, fertilizer and a simulated harvest, on the productivity of both aboveground (leaves and stems) and belowground (rhizomes and/or roots) portions of _Juncus roemerianus_, _Spartina alterniflora_ and _S. cynosuroides_. The elemental composition of the dominant plant species were examined to determine if any of the techniques influence the chemical composition of the plant tissues. Natural stands of the three preceeding species and _S. patens_ and _Distichlis spicata_ were studied for seasonal patterns of productivity, elemental composition and decomposition.

Within the natural communities annual aboveground net primary productivity during the 1977 growing season were: Alabama _J. roemerianus_, 460 g/m^2; Mississippi _J. roemerianus_, 580 g/m^2; _S. alterniflora_ 240 g/m^2; _S. cynosuroides_, 1740 g/m^2; and _Distichlis spicata_, 100 gm/m^2. During the 1978 growing season, productivity of Alabama _J. roemerianus_ was 63 g/m^2, Mississippi _J. roemerianus_ 750 g/m^2, _S. alterniflora_ 110 g/m^2,

and *S. cynosuroides* 1988 g/m^2. Except for *S. cynosuroides*, these productivity estimates are all lower than values reported previously for similar type marshes. Productivity could not be determined of belowground materials although the standing crop down to 20 cm depth was consistently high for all species: 2-4 kg/m^2 for Alabama *J. roemerianus*, 5-7 kg/m^2 for Mississippi *J. roemerianus*, 3-7 kg/m^2 for *S. alterniflora*, 6-9 kg/m^2 for *S. cynosuroides*, 1-3 kg/m^2 for *D. spicata* and 5-8 kg/m^2 for *S. patens*. Belowground biomass includes both live and dead materials which could not be realistically separated. No periodic or seasonal pattern was found for *S. patens*. Thus no productivity estimate could be made.

Annual decomposition of aboveground material was 86% for *Spartina alterniflora*, 44% for *Juncus roemerianus*, 38% for *Distichlis spicata*, 36% for *S. patens*, and 26% for *S. cynosuroides*. There was a general decrease in carbon and hydrogen, and a slight increase in nitrogen, phosphorus and caloric content of decomposing aboveground material during the study.

Annual loss of belowground biomass due to decomposition was most consistent with depth for *J. roemerianus*, losing a maximum of 25% at depths of 11-20 cm. *Juncus* rhizome materials decomposed faster (26.5%) than roots (17.3%). The greatest annual loss belowground was 31% in the 11-20 cm depths for *S. alterniflora*, but only 14% was loss in the upper 10 cm. Loss rates for *S. cynosuroides* were 21% and 7% in the upper and lower 10 cm, respectively. Decomposing belowground material did not exhibit any discernable patterns of change in tissue nutrient or caloric content.

Commercial NH_4NO_3 (34% N) fertilizer was applied once at the beginning of the 1978 growing season to simulate a farm-plantation operation at a dosage (136 g/m^2) estimated to return to the soil approximately the same amount of nitrogen contained in the plants. Annual aboveground net primary productivity increased by 59% in the Alabama J. roemerianus, 76% in the Mississippi J. roemerianus, 82% in the S. alterniflora and 24% in the S. cynosuroides. It appears that short form or high marsh macrophytes responded more to nitrogen enrichment than tall form or low marsh plants.

A single harvest of aboveground material resulted in an increase in annual net productivity of as much as 50% in the Mississippi J. roemerianus and 140% in S. cynosuroides. When the species were reharvested, net productivity increased up to 100% in Mississippi J. roemerianus, 45% in S. cynosuroides and 250% in S. alterniflora. Alabama J. roemerianus showed consistently lowered levels of productivity in harvested plots.

The effects of fire on two tidal marshes in Mississippi was studied for two growing seasons following a fire. Burning the marsh during winter enhanced the productivity (19-27% over control) of the vascular plant community dominated by Spartina cynosuroides during the following growing season. Productivity and the biomass of dead and live material returned to normal levels at the end of the second growing season. On the marsh dominated by Juncus roemerianus, productivity was also higher during the next growing season following a fire (11-33% over control). Associated minor species did not increase their importance significantly relative to the dominant plant species after burning in either marsh community.

Plate counts of microfloral components were developed from subsamples of detritus taken from each litter bag sampling during the decomposition study. Counts were made on four media for bacteria, molds, yeasts and Actinomycetes. In general, all counts were higher than previously thought. All microbial counts were lower for *Spartina alterniflora* belowground detritus than from other marsh grass species. Obligate anaerobes were not detected, since counts were carried out under aerobic conditions. Bacterial and actinomycete counts were depressed from August through December, but began recovery in March. Mold and yeast counts were erratic throughout the study.

Pure cultures of over 60 representative microorganisms were isolated and archived for later study.

Gas analyses of decomposition of *Juncus roemerianus* and *Spartina alterniflora* demonstrated evolution of consistently high levels of CO_2 while half of the *Juncus* samples and two-thirds of the *Spartina* samples also produced large quantities of methane (indicative of anaerobic decomposition).

All pure cultures readily decomposed both plant species under both aerobic and anaerobic conditions. There was a wide range of decomposition rate and a high degree of variability in end products. Protein production in 4 weeks reached as high as 2.2 mg protein/gram of substrate in the *Juncus*, and as high as 2.4 mg protein/gram of substrate for *Spartina*.

Only 4 of 20 pure cultures demonstrated any appreciable cellulose utilization; two primarily aerobically, one essentially anaerobic and one equally well under either oxygen condition.

The faunal communities of three natural marshes (Spartina alterniflora, Juncus romerianus and Distichlis spicata) were investigated over a two year period. Species diversity (yearly and 2 year total) and biomass values of both meio- and macrofaunal components were determined; total reactive carbon, grain size distribution, salinity and temperature were measured on a monthly basis.

The S. alterniflora marsh has the highest macrofaunal and the lowest meiofaunal biomass. Overall meiofaunal diversity is low with lows in spring and fall and highs in summer. Macrofaunal diversity is also low and a decrease is seen over the two years. A total of 11 meiofaunal taxa (esp. Nematoda (72%) and Harpacticoida (25%) and 17 macrofaunal species (esp. Oligochaeta (80%)) were found during the two year period. From a trophic viewpoint this marsh would be characterized as having rich highly fluctuating resources.

The J. roemerianus marsh is characterized by high biomass (both macro- and meiofaunal) and high diversity, (both macro- and meiofaunal). Fluctuations are predictable with summer lows and fall-winter-spring highs. A total of 10 meiofaunal taxa (esp. Nematoda (55%), Harpacticoid Copepoda (26%), Oligochaeta (10%) and 19 macrofaunal species (esp. Oligochaeta (54%), Nereis succinea (13%) and unidentified Capitellidae (10%)) were encountered. The marsh is characterized by a moderate, semistable resource regime.

The D. spicata marsh is characterized by the lowest macrofaunal and moderate meiofaunal biomass. Diversity of both, however, is high with no seasonal trends in variation. Eleven meiofaunal taxa (esp. Nematoda (62%) and Harpacticoid Copepoda (25%) and 17 macrofaunal species (esp. Oligochaeta

(53%) and Neritina reclivata (25%)) were encountered. This marsh is characterized by a poor (low), constant resource regime.

The fauna found within these marshes represent only a few highly specialized forms, however, the abundance of these specialized forms is often high. Biomass values are well within ranges presented for other marsh ecosystems.

Evaluation of the Ecological Role and Techniques for the Management of Tidal Marshes on the Mississippi and Alabama Gulf Coast

OVERVIEW

The measurement of the primary productivity of coastal marsh macrophytes is one of the principal means of estimating the potential production of coastal estuarine systems. Such studies are abundant and have been reviewed by Keefe (1972), de la Cruz (1973), Turner (1976). Because of the increasing human occupancy of coastal areas and the potential uses of some marsh vascular plants (de la Cruz 1976), increased demands are being placed on the coastal zone and its wetlands. Federal, state, and local agencies are beginning to address the question of how best to manage coastal marshlands without decreasing thier productivity or damaging their value to man and wildlife. Several methods of managing marshes and other types of wetlands have been suggested by various studies (e.g., Chabreck 1976, Weller 1978). In this study, burning, harvesting and fertilization were considered as management tools and the effects of these alterations on the structure and productivity of the vegetation, on the decomposition and microbial processes, and on the benthic faunal community were investigated.

Fire is a traditional management technique. Large portions of the marshes along the Gulf Coast are burned regularly by trappers and wildlife managers. The practice is particularly widespread in Louisiana where most of the tidal marshlands are burned annually. Burning the dead vegetation during winter supposedly enhances the growth of marsh plants the following spring which means more food resources for pelt mammals like nutria (*Myocastor coypus*) and muskrat (*Ondatra zibethica*) and for migratory birds (Myers 1956; Hoffpauir 1961; McNease and Glasgow 1970; Chabreck 1976; Whipple and White 1977); and may even provide the proper nesting habitat for some resident ducks (Hackney and Hackney 1976). The ecological effects of fire on marshlands have not been thoroughly studied. Marsh fauna, particularly those species inhabiting the substrate may be susceptible to increased temperature generated immediately near the marsh soil surface. In addition, they are subjected to variable temperatures and humidity as a result of exposure during the regrowth of plant cover. Hoffpauir (1961) found that the temperature 2.79 cm beneath the mud surface increased by 93°C during a fire. This increase in temperature would destroy many of the resident infauna (e.g., marsh clam Polymesoda caroliniana) which play an important role in the energetics of the marsh (Duobinis 1978). Fire generally increases the net primary productivity of a marsh although some marsh communities require more than two years to return to the prefire condition (Hackney and de la Cruz 1977).

Fertilization has been used to promote the growth of marsh plants experimentally (Marshall 1970, Nixon and Oviatt 1973, Sullivan and Daiber 1974, Valiela et al., 1975, 1976, Payonk 1975), and to aid in the establishment of marsh communities on spoil banks (Woodhouses et al., 1974, 1976). Although no large scale application of fertilizers to tidal marshes are known, the possibility of fertilization as a management tool looks promising in the light of low nitrogen and phosphorus concentration in marsh soils.

Various marsh plants are grazed by cattle along the eastern and Gulf coasts (Chabreck 1968). No other regular harvest of marsh plants are employed in the U.S. although the roseau cane or common reed

Phragmites communis is harvested annually in Europe for its cellulose (de la Cruz 1978a). If any of the current works on chemical derivatives (Miles and de la Cruz 1976) and on the pulping potential (de la Cruz and Lightsey, Unpubl. ms.) of marsh plants proves to be of economic value, the prospect of regularly harvesting certain marsh plants for chemicals, cellulose, and other by-products, and employing silviculture techniques to farm marsh grass in plantation fields exists.

This study evaluates the effect of fire, fertilizer and a simulated harvest by clipping on the productivity of both aboveground (leaves and stems) and belowground (rhizomes and/or roots) portions of Juncus roemerianus, Spartina alterniflora and S. cynosuroides in two marsh communities each in St. Louis Bay, Mississippi and Dauphin Island, Alabama. The elemental composition of the dominant plant species were examined to determine if any of the above mentioned techniques influence the chemical composition of the plants. The decomposition rates of both the aboveground portion of the plant (leaves and stems) and belowground portion (roots and rhizomes), and the nutritional changes accompanying decomposition of plant parts to detrital particles were also determined. Natural stands of Spartina patens in Mississippi, and Distichlis spicata in Alabama, were studied for seasonal patterns of productivity, elemental composition and aboveground decomposition.

Macrobenthic, meiobenthic and microbial density and diversity were examined in the natural and selected altered marshes. Their roles in the decomposition processes and other metabolic pathways in the system are integral to the dynamic nature of marshes and their environs.

The various aspects of this research project were conducted in the Gulf Coast marshes of Mississippi and Alabama (Figure 1). The Mississippi study area was located on a marsh island on the western side of St. Louis Bay in Hancock County, Mississippi (Figure 2). The plant communities on this island were previously described by de la Cruz (1973) and Gabriel and de la Cruz (1974). The Juncus roemerianus marsh was located on the southwestern side of the island approximately 100 m south of a small tidal creek. The Spartina cynosuroides community was located on the eastern side of the island. The two marshes are not monotypic communities and each harbors at least three minor associated species.

In Alabama, a Juncus roemerianus marsh and Spartina alterniflora marsh, each on the leeward shore of Dauphin Island, Mobile County, were used as study areas. An additional study site at Point aux Pins on the mainland just east of the Mississippi-Alabama line was utilized for the study of Distichlis spicata. Species composition and environmental setting of the two Dauphin Island study sites have been previously described by Stout (1978). The D. spicata study area is located in a typical Gulf Coast "salt pan" and consists of a broad bordering band of Distichlis with minor contributions from Salicornia sps. and Batis maritima. The substrate is sand with interstitial salinities well above seawater.

Ten square meter study plots each were established in the J. roemerianus (Miss.) J. roemerianus (Ala.), S. alterniflora and S. cynosuroides communities. There was at least a 2 m buffer zone between areas. All study sites in each marsh type were within a relatively small uniform area with respect to topography, hydrology, and fauna. The experimental plots were marked with labelled wooden stakes and sampling transects across each plot were laid out along an east-west direction. The four experimental plots in 1977 and six plots in 1978 were prepared and

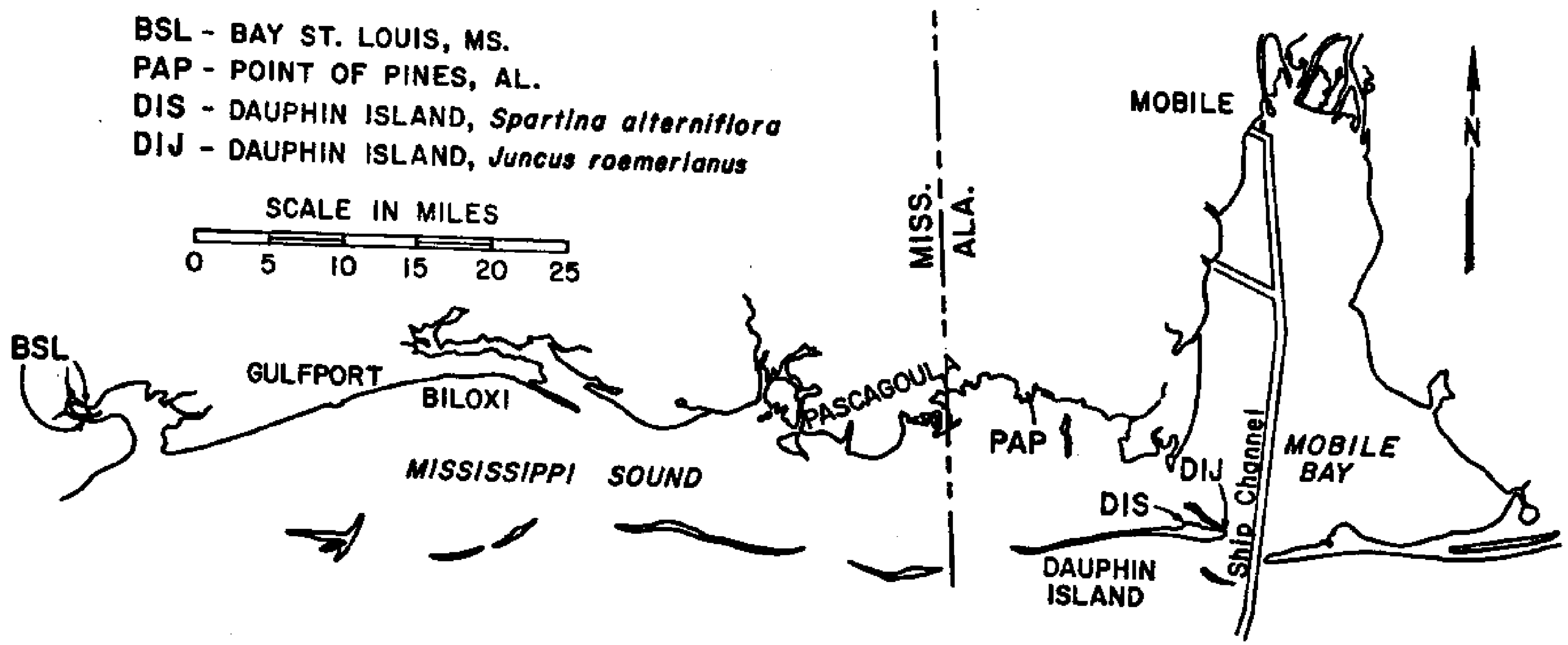
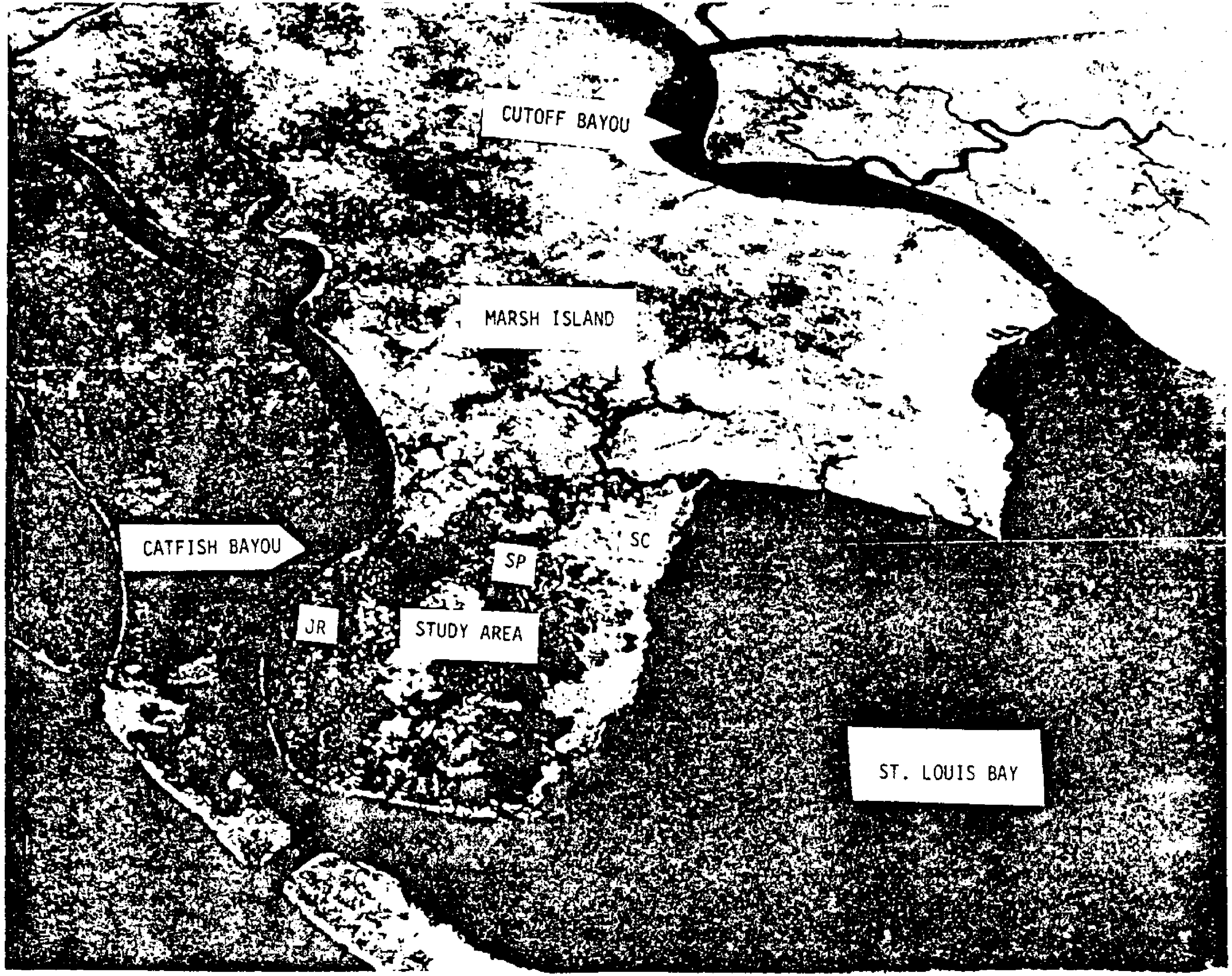


FIG. I. STUDY SITE LOCATIONS.


CUTOFF BAYOU
MARSH ISLAND
CATFISH BAYOU
SC
SP
JR
STUDY AREA
ST. LOUIS BAY

designated as follows:

1. Cut - The plot was hand-clipped as near ground level as possible and all dead and living material removed from the area.
2. Fertilized 1977 - The plot was treated with 7.1 kg of commercial fertilizer (13-13-13) by hand broadcast as evenly as possible with minimum disturbance of the area.
3. Fertilized 1978 - The plot was treated with 136 g/m^2 of commercial NH_4NO_3 (34% N) with some technique as in 1977.
4. Burn - The plot was burned to the ground.
5. Control - Natural undistrubed plot.
6. 1978 recut.
7. 1978 reburn.

A single 10 x 10 m study plot each was established in the undisturbed *Spartina patens* and *Distichlis spicata*. No experimental treatments were applied to either of these species.

The results of these studies are presented as separate papers addressing each of the various topics that make up this project.

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PART I

FLORAL DYNAMICS

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Standing Crop and Productivity of Dominant Marsh Communities in the Alabama - Mississippi Gulf Coast

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ABSTRACT

Standing crop of above- and belowground biomass of *Juncus roemerianus*, *Spartina alterniflora*, and *Distichlis spicata* in Alabama and *Juncus roemerianus*, *Spartina cynosuroides* and *Spartina patens* in Mississippi were determined monthly be means of the harvest methods. Six replicates of 0.25 m^2 quadrats for aboveground and six of 10 cm diameter cores for belowground were collected and their mean values were used in estimating the annual net primary productivity from a predictive periodic maximum - minimum model corrected for die-out. Annual aboveground net primary productivity during the 1977 growing season were: Alabama *J. roemerianus*, 460 g/m^2; Mississippi *J. roemerianus*, 580 g/m^2; *S. alterniflora*, 240 g/m^2; *S. cynosuroides*, 1740 g/m^2; and *Distichlis spicata*, 100 gm/m^2. During the 1978 growing season, productivity of Alabama *J. roemerianus* was 63 g/m^2, Mississippi *J. roemerianus* 750 g/m^2, *S. alterniflora* 110 g/m^2, and *S. cynosuroides* 2860 g/m^2. Except for *S. cynosuroides*, these productivity estimates are all lower than values reported previously for similar type marshes. Productivity could not be determined of belowground materials although the standing crop down to 20 cm depth was consistently high for all species: 2-4 kg/m^2 for Alabama *J. roemerianus*, 5-7 kg/m^2 for Mississippi *J. roemerianus*, 3-7 kg/m^2 for *S. alterniflora*, 6-9 kg/m^2 for *S. cynosuroides*, 1-3 kg/m^2 for *D. spicata* and 5-8 kg/m^2 for S. patens. Belowground biomass includes both live and dead materials which could not be realistically separated. No periodic or seasonal pattern was found for *S. patens*. Thus no productivity estimate could be made.

INTRODUCTION

Coastal marshes are commonly characterized as sites of extremely high primary production. Available data, however, are insufficient to support or refute such a generalization. It is more likely that marshes differ considerably in their productivity. The diverse nature of marshlands along the Gulf Coast offers an ideal opportunity to test differences in the primary productivity of different species of marsh plants. The marsh types described by Uhler and Hotchkiss (1968) as irregularly flooded marsh dominated by *Juncus roemerianus*, waterlogged salt flats of *Distichlis spicata*, and salt meadows of *Spartina alterniflora* and lush stands of *Spartina cynosuroides* are found in Alabama-Mississippi coastal estuaries. Mixed stands of several marsh plant species are common. As many as 34 species may be found in one locality although only a few of these are of major importance (Gabriel and de la Cruz 1974).

Primary production studies in the northern Gulf of Mexico marshes are few. Kirby (1971) reported an annual net production of 1006-1410 gm^{-2} for an *S. alterniflora* marsh in Louisiana. Eleuterius (1972) estimated production value of about 2000 gm^{-2} yr^{-1} for a *J. roemerianus* marsh in Mississippi. More recently studies on marshes at St. Louis Bay estuary in Mississippi showed production value of 1-2 $kg/m^2/yr$ (Gabriel and de la Cruz 1974; de la Cruz 1974). In all these studies, only the annual net primary productivity of aboveground materials was measured.

MATERIALS AND METHODS

Six 0.5 x 0.5 m (0.25 m^2) plots were collected monthly from April through September 1977 of the following marsh types: J. roemerianus, Spartina alterniflora and Distichlis spicata in Alabama and J. roemerianus, Spartina cynosuroides, and Spartina patens, in Mississippi. All living and dead materials were removed from each harvested plot including litter. Using the wooden stakes as reference points, a random stratified sampling procedure was used. Such a prodedure randomly selected certain areas within each study plot without causing severe trampling damage to the marsh. The six replicates were randomly collected from within this subarea.

Each sample was transported to the laboratory where it was separated into living and standing dead plants (those plants that were dead, but still attached to the roots or rhizomes), and litter on the ground. Living plants were separated according to species. All separated material was dried at 103^{o} C to constant weight and weighed. A subsample from each live sample was retained each collection period for caloric and ash-free dry weight analyses.

The estimate of net primary productivity for any area varies depending on the method of estimation, species of vascular plant, geographic area, etc. (Turner 1976, de la Cruz 1978b). In this study, we estimated productivity according to a general periodic model designed by Hackney and Hackney (1978). Essentially, this is a max.-min. technique except that the maximum and minimum values are extracted from a predicted periodic curve based on all of the data. The standard max.-min. technique uses only the highest and lowest actual values and essentially ignores the rest of the data.

Six belowground samples were collected from each plot at the same time as the aboveground with a coring device (10 cm diameter) previously described by de la Cruz and Hackney (1977). Each core was cut into 2 sections, 0-10 and 10-20 cm, referred to as sections A and B, respectively. Most of the living subterranean material were previously observed to be located in the upper 20 cm of the marsh substrate (de la Cruz and Hackney 1977, Stout 1978). Each core section was transported to the laboratory and washed thoroughly, but carefully, in running tap water over a 1 mm sieve. Living and dead rhizome/root materials were not separated. Each core was dried to a constant weight at 103° C. A subsample from the A and B core-section was retained each collection period for caloric and ash-free dry weight analyses.

Monthly sampling of aboveground materials was continued in 1978 in the two J. roemerianus, S. alterniflora, and S. cynosuroides communities to determine second year productivity.

RESULTS AND DISCUSSION

JUNCUS ROEMERIANUS MARSH - MISSISSIPPI

The J. roemerianus marsh reached its peak total live biomass in July 1977 with 1060 g/m^2 and in September 1978 with 1155 g/m^2 (Table 1). The biomass of dead standing material was constantly high throughout both years. During all collections there were almost 300 g/m^2 of litter in 1977 and generally more litter in 1978 (Table 1).

Minor species associated with J. roemerianus in Mississippi were an important component of the plant community biomass. These were, in order of relative importance by weight, Spartina cynosuroides, Fimbri-

Table 1. Average biomass ($\bar{x}$) and standard deviation (S) of live and standing dead plants shoots, total litter, number of minor species, and total live biomass of all species (g/m^2) in the J. roemerianus community in Mississippi.

DATE	LIVE		DEAD		LITTER		Assoc. Minor Spp.	Total Live Biomass of all species	
	$\bar{x}$	S	$\bar{x}$	S	$\bar{x}$	S	$\bar{x}$ no.	$\bar{x}$	S
02-14-77	581.3	139.3	860.7	242.4	284.7	60.6	1.0	604.3	150.9
04-27-77	379.2	138.8	598.0	146.4	230.1	56.8	1.3	468.3	163.6
05-25-77	448.0	89.8	557.3	138.2	502.7	126.3	2.0	665.0	184.0
06-29-77	805-2	112.4	801.3	122.7	381.5	123.7	3.0	982.0	111.8
07-29-77	872.0	187.2	798.0	130.5	204.1	66.9	2.7	1060.0	235.7
08-26-77	740.0	146.8	1051.3	149.3	390.1	117.3	2.7	948.3	157.4
09-17-77	538.8	66.0	984.0	90.9	242.1	70.1	1.3	684.6	119.3
11-26-77	481.3	166.9	799.6	346.2	261.4	39.9	2.0	601.4	137.1
02-18-78	546.7	22.22	641.3	29.26	390.0	19.42	1.2	599.0	95.08
04-23-78	526.7	27.25	859.3	45.32	220.8	7.36	3.0	654.67	113.58
05-27-78	607.4	59.62	615.3	22.74	252.0	11.40	3.9	959.33	97.31
06-24-78	649.3	16.35	611.3	12.27	365.3	11.29	3.2	989.33	279.01
07-28-73	474.0	5.4	1203.3	44.8	324.0	14.1	3.0	812.0	85.19
08-26-78	610.0	41.5	306.0	23.6	449.3	18.3	2.3	994.7	224.94
09-22-78	586.6	16.7	567.3	30.5	736.6	38.2	2.7	1155.33	258.73
10-28-78	598.7	27.0	952.7	60.8	466.0	27.9	2.3	980.7	181.33
11-26-78[1]	-	-	-	-	-	-	-	-	-
12-16-78	637.3	54.5	910.7	28.9	734.7	35.5	2.3	885.33	295.59

[1] Samples were lost due to fire in the drying oven.

stylis castanea, S. patens, Distichlis spicata, Panicum amarulum and Boltonia asteroides. Lilaeopsis chinensis was also found but was not harvested because of its short, prostrate growing characteristic. The minor species were not an important component of the plant community before March (less than 10%), but as the growing season progressed they became more important. In May associated minor species accounted for 32.6% of the plant biomass and then decreased to approximately 20% for the remainder of the study.

Aboveground primary productivity based on the predictive periodic model (PPM) revealed values of 584 g/m^2 in 1977 and 753 g/m^2 in 1978. As can be seen in Figure 1, the PPM for 1977 growth pattern followed a single harmonic curve while 1978 has a two harmonic curve. The 2-peak biomass observed in 1978 growing season occurred in both the Mississippi and Alabama forms of J. roemerianus. The only explanation for this is the great difference in weather conditions - the earlier and more severe winter conditions in 1977 suppressed the otherwise continuous growth of Juncus. This indicates that the growth pattern and productivity of a J. roemerianus marsh can vary from year to year depending on climate and weather changes.

Analyses of the belowground biomass revealed no apparent annual pattern (Table 2). The biomass in the top 10 cm was always higher than the biomass in the 11-20 cm level during all months. The total belowground biomass was lowest in May (4.92 kg/m^2) and highest (6.11-6.41 kg/m^2) in June and November. There was less variation in the month-to-month biomass at the 11-20 cm level. Due to the limited data, no belowground productivity estimates could be made.

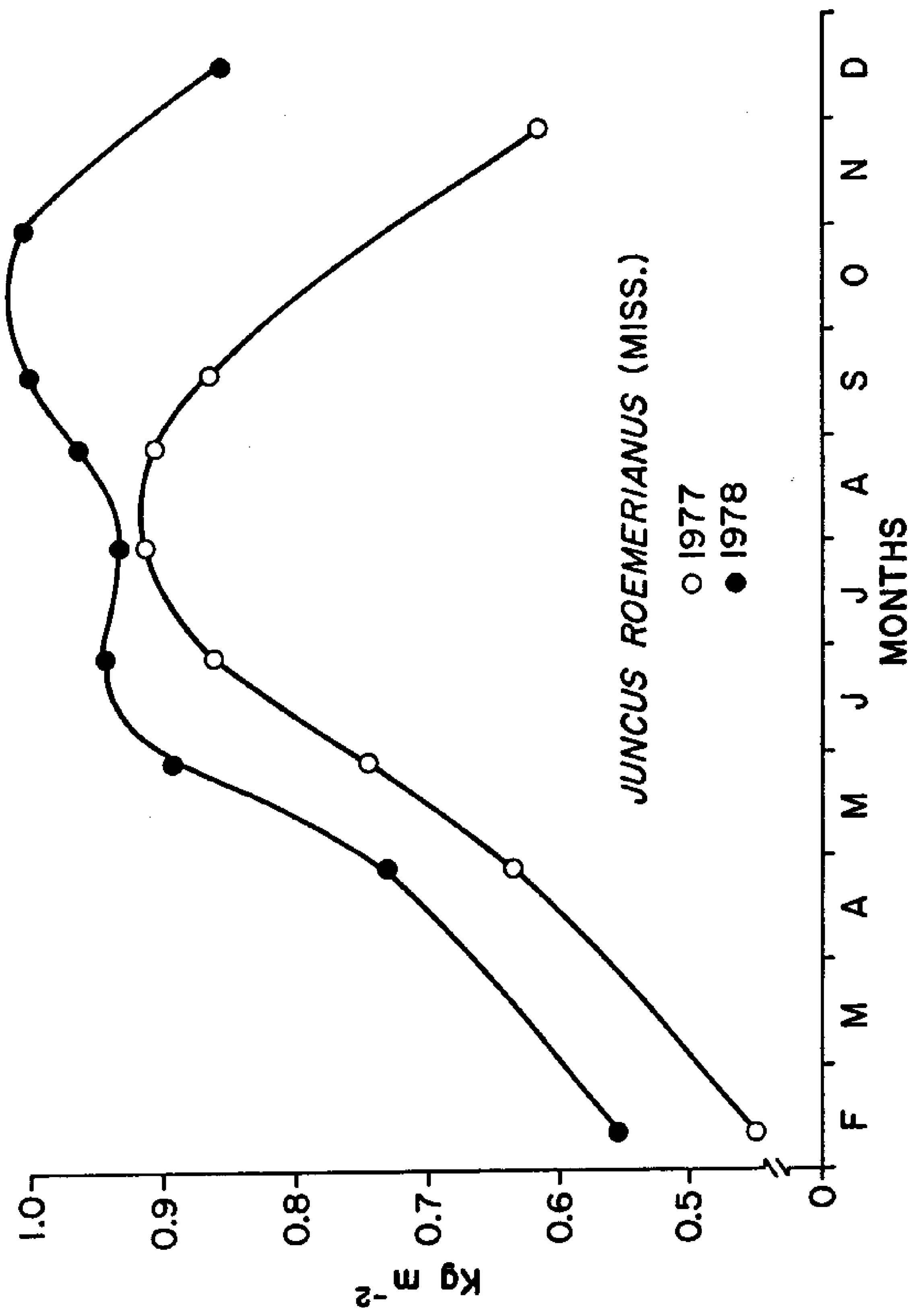

Figure 1. Periodic max.-min. curves for the Mississippi J. roemerianus community.

Table 2. Standing crop of belowground biomass (kg/m^2) in the Mississippi *J. roemerianus* marsh at the 0-10 cm and the 11-20 cm depth levels.

DATE	0-10 cm DEPTH LEVEL	11-20 cm DEPTH LEVEL	TOTAL
02-15-77	3.24	2.42	5.66
04-27-77	3.00	2.90	5.90
05-25-77	2.46	2.46	4.92
06-29-77	3.88	2.53	6.41
07-29-77	2.24	2.30	4.54
08-26.77	2.84	2.23	5.07
09-17-77	3.88	2.23	6.11
11-26-77	2.86	2.57	5.43

JUNCUS ROEMERIANUS MARSH - ALABAMA

Natural stands of Juncus roemerianus showed no apparent seasonal pattern in biomass production over the study period (Table 3). Monthly standing crop was different in the two years, thus, minimum and maximum biomass did not occur in the same month. Dead biomass comprised over 50 percent of total standing biomass at all times, contributing over 70% throughout the winter months. Standing crop values were significantly higher than in the Mississippi Juncus marsh but the productivity of 455 g/m^2 was lower. The large quantities of standing dead stems create a dense cover which may contribute to the lack of minor species within this community. No measurable contribution to biomass was found for minor species, although occasional single plants were observed. The Alabama study marsh is essentially a monospecific community of J. roemerianus. While the Alabama Juncus marsh is quite different from that of Mississippi for being more saline and monotypic, the growth pattern in 1978 also showed a two harmonics-curve (Figure 2) indicating the greater influence of climate and weather.

Analysis of belowground biomass production revealed a rather uniform biomass concentration. Levels of biomass were essentially similar at the 0-10 cm and 11-20 cm depths (Table 4). Though belowground biomass appeared to decrease in the top 10 centimeters through the summer months, no seasonal pattern was determined.

SPARTINA CYNOSUROIDES MARSH

The standing crop summarized in Table 5 indicates once again the difference between 1977 and 1978 plant growth and production. Since most of the living leaves and stems of plants in this community die

Table 3. Average biomass ($\bar{x}$) and standard deviation (S) of live and standing dead plant shoots and total plant biomass (g/m^2) in the J. roemerianus community in Alabama.

DATE	LIVE		DEAD		TOTAL BIOMASS	
	$\bar{x}$	S	$\bar{x}$	S	$\bar{x}$	S
02-17-77	695.8	158.2	2009.1	312.0	2704.9	451.5
04-20-77	742.0	123.0	1512.0	214.0	2254.6	281.8
05-19-77	857.0	249.5	1610.9	143.5	2467.9	246.4
06-22-77	803.6	187.0	1609.9	258.2	243.5	418.7
07-26-77	1009.2	378.5	1270.4	195.3	2279.6	531.4
8[1]	-	-	-	-	-	-
09-07-77	379.7	83.8	898.6	310.4	1278.3	390.5
11-28-77	544.5	69.8	1879.1	219.4	2423.6	175.7
02-15-78	422.57	76.83	1235.88	333.1	1657.6	378.19
03-15-78	501.66	90.96	1183.7	304.22	1685.29	363.83
04-19-78	558.9	186.77	1649.08	244.45	2208.78	373.66
05-24-78	230.95	51.22	573.4	332.75	804.35	318.20
06-28-78	365.75	52.46	582.46	152.04	948.21	125.50
07-27-78	506.82	68.01	624.27	168.19	1131.09	134.44
09-01-78	549	127.69	573.14	76.59	1122.14	146.92
10-06-78	429.76	94.04	971.03	157.6	1400.84	204.12
12-05-78	773.05	120.49	759.04	288.81	1532.03	112.41

[1] No samples were collected in August 1977.

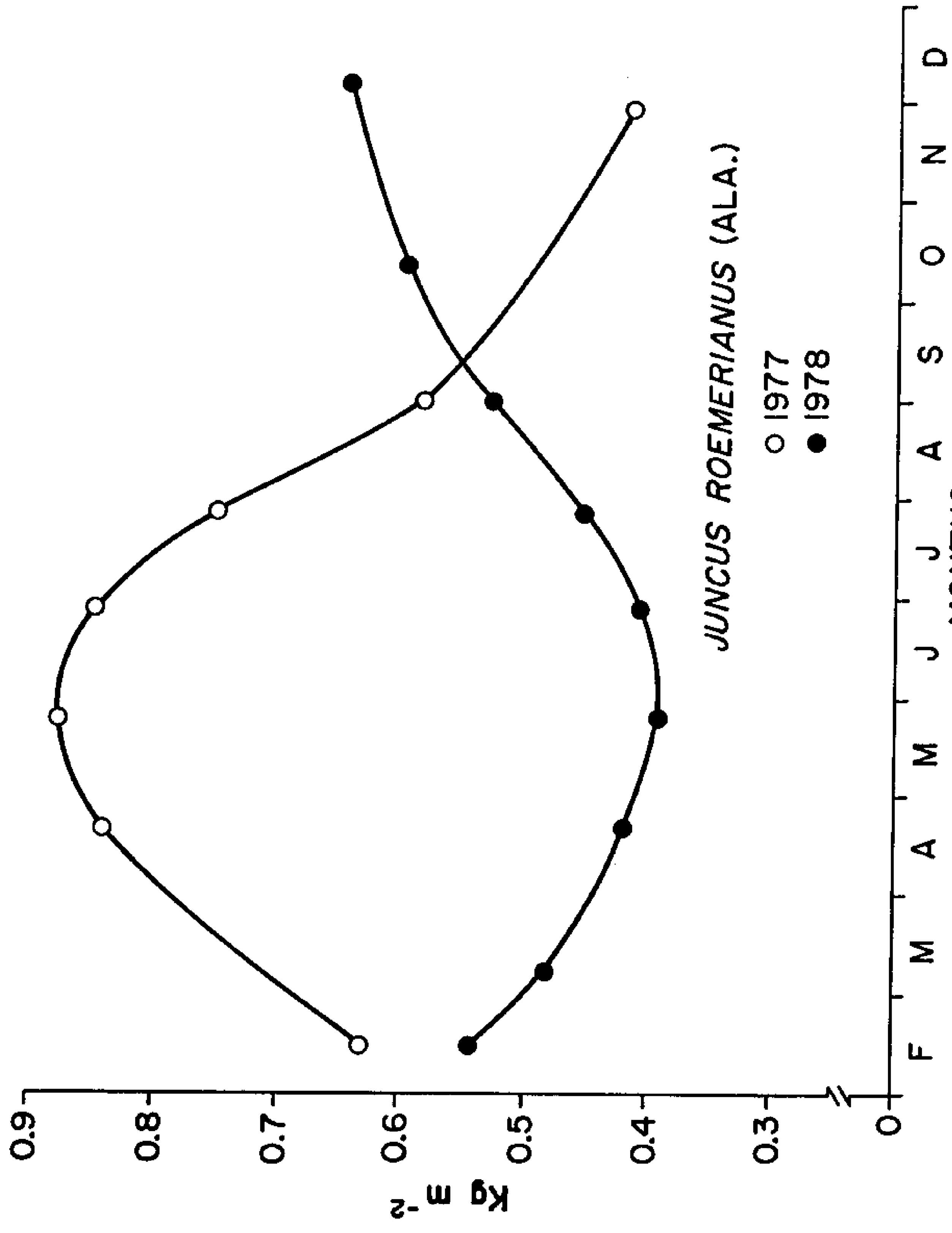

Figure 2. Periodic max.-min. curves for the Alabama J. roemerianus community.

Table 4. Standing crop of belowground biomass (Kg/m^2) in the Alabama *J. roemerianus* marsh at the 0-10 cm and the 11-20 cm depth levels.

DATE	0-10 cm DEPTH LEVEL	11-20 cm DEPTH LEVEL	TOTAL
02-17-77	2.48	1.03	3.51
04-20-77	1.99	1.32	3.31
05-19-77	1.96	1.37	3.33
06-29-77	0.99	1.23	2.22
07-26-77	0.92	1.51	2.43
09-07-77	1.69	2.13	3.82
11-28-77	2.18	1.01	3.19

Table 5. Average biomass ($\bar{x}$) and standard deviations (S) of live and standing dead plant shoots, total litter, number of minor species, and total live biomass of all species g/m^2 in the _S. cynosuroides_ community in Mississippi.

DATE	LIVE		DEAD		LITTER		ASSOC. MINOR SPP.	TOTAL LIVE BIOMASS OF ALL SPECIES	
	$\bar{x}$	S	$\bar{x}$	S	$\bar{x}$	S	$\bar{x}$ NO.	$\bar{x}$	S
02-14-77	0[1]	0	2172.6	426.4	785.4	163.0	0.3	120.7	152.3
04-27-77	376.3	110.3	1218.0	498.5	864.0	111.9	0.5	397.7	95.7
05-25-77	700.3	311.5	1435.3	621.5	988.7	93.8	0.8	865.3	291.6
06-29-77	1220.0	598.5	1656.7	318.9	1076.0	143.4	0.5	1279.7	557.8
07-29-77	1210.0	400.1	1122.7	122.6	792.7	148.9	0	1210.0	400.1
08-26-77	1072.0	300.0	1160.0	138.3	767.4	184.3	1.5	1557.3	350.6
09-17-77	1035.3	360.0	1014.7	282.2	1137.4	204.5	0.5	1122.7	345.9
11-26-77	0	0	1806.7	221.3	804.1	188.1	0.2	0.7	1.6
02-18-73	0	0	1855.3	64.94	1437.3	50.50	0	0	0
04-23-78	228.7	20.30	279.3	86.06	1235.3	89.78	0.3	0	0
05-27-78	498.7	44.49	1141.3	48.32	1202.7	64.22	1.0	766.0	178.97
06-24-78	790.0	47.75	928.0	75.74	1092.7	67.40	1.0	1219.3	111.07
07-23-78	1296.7	28.0	990.7	92.4	983.3	25.8	1.0	1927.3	214.74
08-26-78	943.3	77.6	1766.6	147.3	1400.0	61.8	1.0	1298.7	285.54
09-22-78	1660.6	78.1	1426.6	106.3	1764.0	60.3	0.0	1660.67	312.34
10-28-78	1203.3	43.8	1341.6	76.6	1296.7	41.3	0.5	1360.67	264.02
11-26-73	581.3	41.5	2680.7	162.6	1369.3	92.7	0.2	606.0	171.52
12-16-78	206.0	61.3	2376.0	134.2	1342.0	172.0	0.7	354.67	63.57

[1] 0 means no living plants during this winter month.

during winter there were few living plants before February 15 and after November 28, 1977. However, there were live plants until December 1978, and the milder winter in 1978 induced higher maximum biomass of 1661 g/m^2 in June as compared to 1220 g/m^2 in the same month in 1977. Typically the standing dead material in S. cynosuroides marsh consists of three age classes. The oldest year class (3 year) consists of only the lower portions of tough stems while the second year age class includes the whole intact shoot. The newly dead plants include the stem and all or most of the foliage. This, of course, depends on the time of the year with the previous description best suited to the community at the end of the growing season. The addition of the new year's growth to the standing dead component increased the standing dead plant material, for example, from 1014 g/m^2 to 1806.7 g/m^2 two months earlier. During the months of the growing season, the standing dead plant material decreased as the stems and leaves fell to the ground and entered the litter component (Table 5). Because flooding does not occur regularly on this marsh, and because of the dense vegetation, litter tends to stay within the community. Thus, litter increased almost proportionately to the decrease of standing dead material in the spring.

Six additional vascular plant species were collected in the S. cynosuroides marsh. Panicum virgatum, Scirpus americanus and S. robustus were found regularly while Juncus roemerianus, Distichlis spicata and Boltonia asteroides were only occasionally collected. P. virgatum was the most important minor species which accounted for as much as 40% of the standing biomass during parts of the growing season. Scirpus spp. were most important early in the growing season,

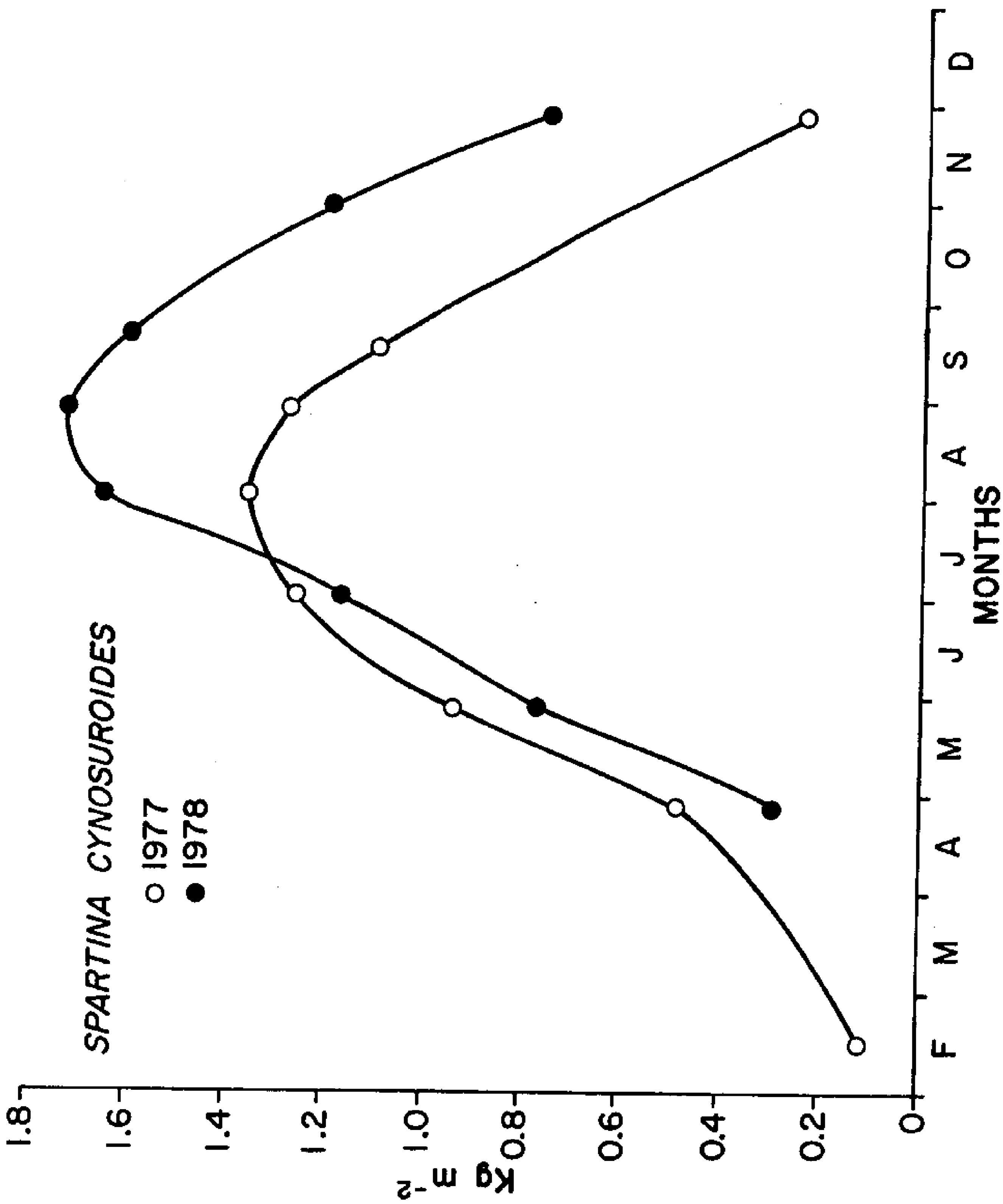

Figure 3. Periodic max.-min. curves for the S. cynosuroides marsh.

but were mostly dead by the end of June. During the winter and at the beginning and end of the growing season the associated species constituted 100% of the living plant biomass, although the amount of living plant material in these communities was low during these periods.

Based on the PMM model depicted in Figure 3, net aboveground primary was 1737 $g/m^2/yr$. During the second year, corrected biomass was much higher and beginning July until winter yielded a higher production value (2860 g/m^2) over that of the previous year.

There were no significant statistical differences among the belowground biomass values at either depth level. The root-rhizome biomass was significantly higher in the 11-20 cm level than in the 0-10 cm level. In general, the maximum biomass occurred during the summer in July and August (Table 6). This peak occurred at the same time as the high aboveground biomass.

<u>SPARTINA</u> <u>ALTERNIFLORA</u> MARSH

Within the natural plot of <u>S</u>. <u>alterniflora</u> live and dead biomass increased through the warm growing season, to a peak of 413.6 g/m^2 in June, then declined to a winter low of 86.1 g/m^2 in November (Table 7). Conversely, dead biomass peaked in the winter during the minimal growth period with a peak of 520.0 g/m^2 in February declining through the warmer months to a low of 141.3 g/m^2 in July. Movement of biomass from the living component to the dead was demonstrated by an approximate one month lag in response of the dead compartment. Living material was found at each sampling date, evidence of some growth and production year-round. 1978 showed similar biomass

Table 6. Standing belowground biomass (kg/m^2) in the *S. cynosuroides* marsh in the 0-10 cm and 11-20 cm depth levels.

DATE	0-10 cm DEPTH LEVEL	11-20 cm DEPTH LEVEL	TOTAL
02-15-77	2.84	4.07	6.91
04-19-77	2.64	4.66	7.30
05-24-77	2.37	3.92	6.29
06-28-77	2.80	4.55	7.35
07-28-77	3.97	4.88	8.85
08-26-77	2.25	4.75	7.00
09-17-77	2.85	4.19	7.04
11-26-77	2.23	3.51	5.74

Table 7. Average biomass ($\bar{x}$) and standard deviation (S) of live and standing dead shoots and total aboveground biomass (g/m^2) in the *S. alterniflora* community in Alabama.

DATE	LIVE $\bar{X}$	LIVE S	DEAD $\bar{X}$	DEAD S	TOTAL BIOMASS $\bar{X}$	TOTAL BIOMASS S
02-18-77	242.0	203.0	520.0	107.0	761.7	293.1
04-26-77	199.0	-	413.0	44.0	612.4	96.5
05-23-77	299.4	96.4	443.7	95.8	743.1	183.8
06-23-77	413.6	85.7	327.7	100.1	741.3	134.3
07-27-77	406.6	118.7	141.3	61.5	547.7	170.6
8[1]	-	-	-	-	-	-
09-12-77	162.8	67.9	155.4	27.3	318.2	58.6
11-29-77	86.1	71.4	272.6	53.7	358.7	92.6
02-16-78	309.69	78.07	197.01	55.32	506.69	74.30
03-17-78	205.67	48.72	384.9	107.38	590.57	101.85
05-02-78	231.55	93.27	246.61	30.96	478.16	141.89
06-14-78	351.86	113.93	174.17	30.24	526.03	128.58
06-26-78	271.07	31.48	102.98	40.43	374.05	63.19
08-01-78	514.59	50.67	87.21	25.83	601.8	59.27
09-09-78	473.05	34.23	94.77	40.37	567.81	56.46
10-09-78	680.8	102.28	50.4	14.32	731.2	105.72
12-07-78	641.61	119.27	79.58	36.2	721.19	124.8

[1]No samples were collected in August 1977.

patterns as 1977 except a much lower dead:live ratio during the later part of 1978.

Aboveground primary productivity based on the PPM curves (Figure 4) was higher in 1977 (240 g/m^2) than in 1978 (140 g/m^2).

No seasonal patterns of root/rhizome biomass production can be seen in the _S. alterniflora_ marsh. There was slightly greater biomass in the lower 11-20 cm portion (Table 8).

DISTICHLIS SPICATA MARSH

Productivity of natural _Distichlis spicata_ was seasonal. Total biomass increased to a June peak of 673.9 g/m^2 of which 470 g/m^2 was dead and 203.7 g/m^2 was living (Table 9). Living biomass declined after peak production while dead biomass remained moderately high. Dead material contributed greater than 50% to total biomass throughout the study.

The periodic model for _Distichlis spicata_ generated a max.-min. curve very close to the actual curve (Figure 5) and yielded a productivity estimate of 100.2 g/m^2.

There was no significant seasonal variation in belowground biomass production in either depth segment of _D. spicata_ cores. However, the 0-10 cm segment obviously produces greater biomass (Table 10) than in the 11-20 cm portion, respective mean values determined to be 1431.9 g/m^2 and 315.6 g/m^2.

SPARTINA PATENS MARSH

No periodic or seasonal pattern was found in the _S. patens_ stems and shoots (Table 11). Thus, no productivity estimate could be made. Living biomass ranged between 140.7 to 68.7 $g/0.1\ m^2$ during the study. This variability was apparently due to the small sample size neces-

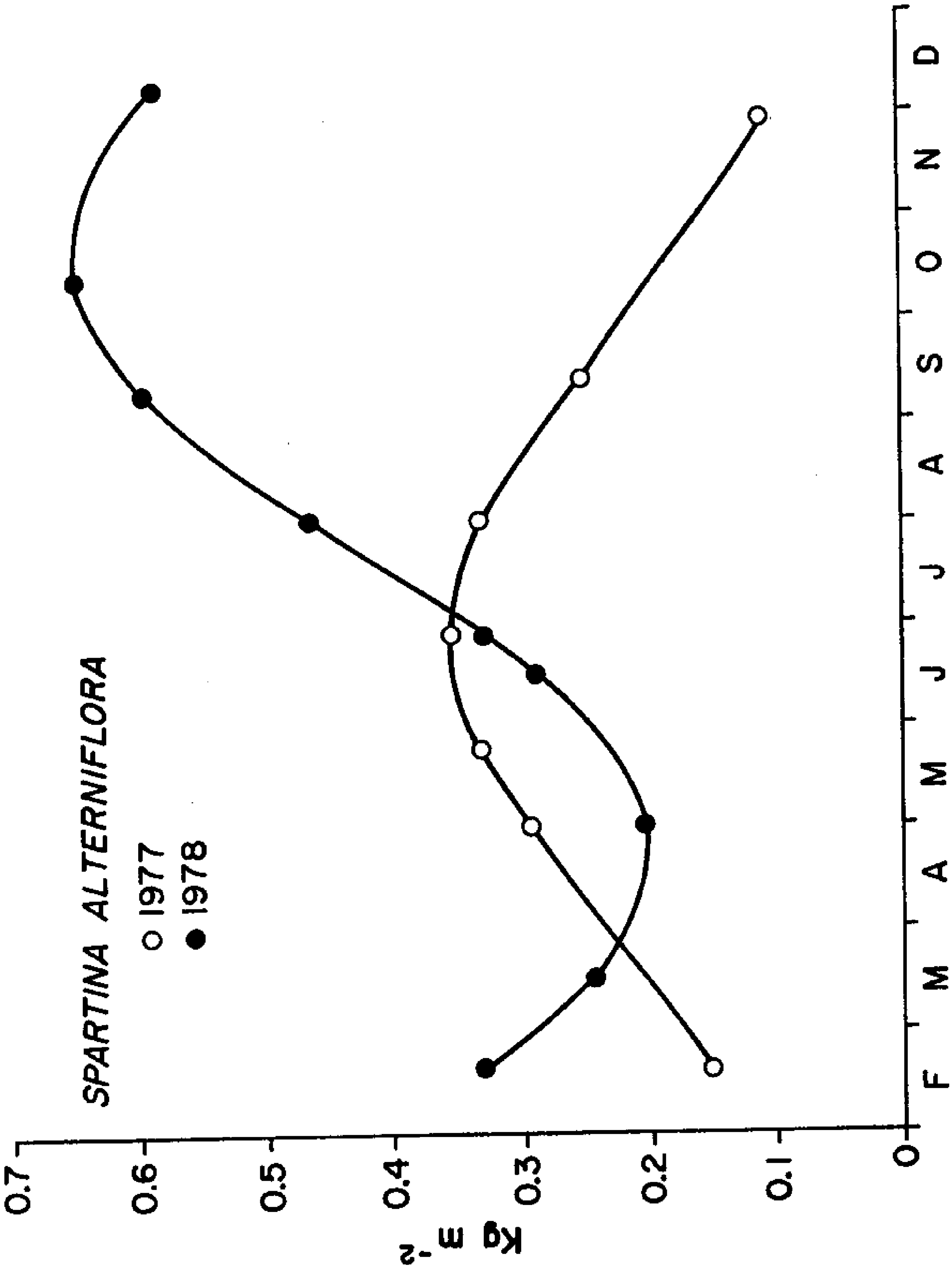

Figure 4. Periodic max.-min. curves for the S. alterniflora marsh.

Table 8. Standing crop of belowground biomass (kg/m^2) in the *Spartina alterniflora* marsh at the 0-10 cm and the 11-20 cm depth levels.

DATE	0-10 cm DEPTH LEVEL	11-20 cm DEPTH LEVEL	TOTAL
02-18-77	2.38	3.10	5.48
04-26-77	2.85	4.01	6.86
05-23-77	2.36	3.65	6.01
06-29-77	2.63	3.72	6.35
07-27-77	2.93	1.95	4.88
09-12-77	2.85	2.25	5.10
11-29-77	1.45	2.64	1.09

Table 9. Mean biomass and standard deviation of live and dead shoots and total biomass (g/m^2) in the D. *spicata* community in Alabama.

DATE	LIVE		DEAD		TOTAL BIOMASS	
	$\overline{X}$	S	$\overline{X}$	S	$\overline{X}$	S
02-21-77	97.0	32.0	872.0	123.0	968.3	131.3
04-27-77	94.0	29.0	292.0	60.0	386.1	72.2
05-24-77	130.8	19.3	376.9	96.2	507.8	97.4
06-21-77	203.7	29.8	470.2	193.7	673.8	174.6
07-25-77	150.9	30.9	295.9	28.5	446.8	52.0
08-25-77	142.9	21.7	324.4	62.1	467.3	71.5
09-14-77	127.5	29.5	351.8	74.9	479.2	96.9
11-30-77	130.2	29.7	239.8	93.6	370.0	120.8

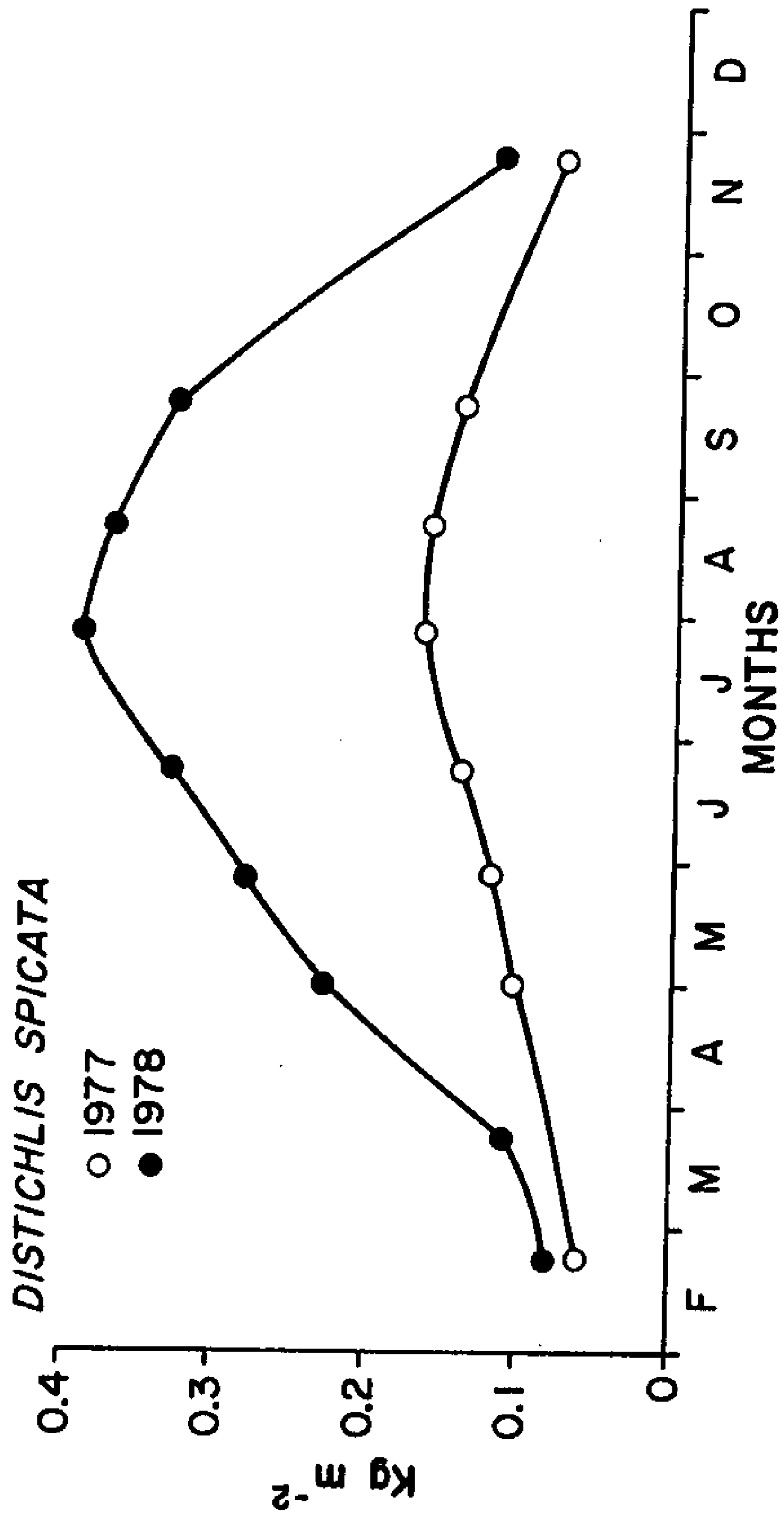

Figure 5. Periodic max.-min. curve for D. spicata community.

Table 10. Standing crop of belowground biomass (kg/m^2) in the _D. spicata_ marsh at the 0-10 cm and 11-20 cm depth levels.

DATE	0-10 cm DEPTH LEVELS	11-20 cm DEPTH LEVELS	TOTAL
02-21-77	1.36	0.22	1.32
04-27-77	1.02	0.09	1.11
05-24-77	1.11	0.10	1.21
06-21-77	1.38	0.27	1.61
07-25-77	1.84	0.36	2.20
08-25-77	1.17	0.41	1.58
09-14-77	1.09	0.13	1.22
11-30-77	2.50	0.95	3.45

Table 11. Average and standard deviation of live and standing dead shoots, total litter, and the total live plant biomass ($g/0.1\ m^2$) in the _S. patens_ community in Mississippi.

DATE	LIVE		DEAD		LITTER		ASSOC. MINOR SPP.	TOTAL LIVE BIO-MASS OF ALL SPECIES	
	$\bar{x}$	S	$\bar{x}$	S	$\bar{x}$	S	$\bar{x}$ NO.	$\bar{x}$	S
02-15-77	125.3	48.2	790.0	331.7	86.0	32.6	0.2	144.0	59.5
04-27-22	68.7	33.0	148.7	55.2	6.7	4.1	0	68.7	33.0
05-25-77	91.3	26.2	33.3	26.0	18.0	13.6	0	91.3	26.2
06-29-77	119.7	29.0	92.3	33.8	161.0	92.0	0	119.7	29.0
07-29-77	83.7	63.6	26.7	28.8	4.0	0.02	0.5	91.7	60.6
08-26-77	140.7	43.7	73.3	34.3	9.7	5.1	0.5	145.3	42.3
09-17-77	78.5	28.9	54.0	25.6	19.4	47.7	0.7	89.2	26.9

sitated by the small area of this community. The biomass of dead standing material varied between 33.3 and 790 g/0.1 m^2 (Table 10). Liter was also variable with between 4.0 to 161. g/0.1 m^2 collected. This was almost a monotypic community of S. patens (Table 11). Only two other species, J. roemerianus and Scirpus robustus, were infrequently collected.

The biomass of roots and rhizomes ranged from 2.6355 to 4.4053 kg/m^2 in the 0-10 cm zone and from 2.6483 to 3.4376 kg/m^2 in the 11-20 cm zone (Table 12). Because of the variability among the six replicates collected each sampling period, no productivity estimates were made.

CONCLUSION

On the basis of this two-year study, we can make the following conclusions:

1. The aboveground primary productivity of marsh vascular plants can vary from year to year due to extreme changes in climate and weather.

2. The vegetational structure, phenology, and productivity of the sedge Juncus roemerianus is different from the Spartina grasses.

3. Except for Spartina cynosuroides, the aboveground primary productivity values obtained in this study are lower than those reported previously for the same types of marsh communities.

4. Annual productivity of belowground materials are difficult to measure and require the separation of live from dead tissues.

Table 12. Standing crop of belowground biomass (kg/m^2) in the *S. patens* community in the 0-10 cm and 11-20 cm depth levels.

DATE	0-10 cm DEPTH LEVELS	11-20 cm DEPTH LEVELS	TOTAL
02-15-77	3.23	2.89	6.12
04-27-77	3.11	3.44	6.55
05-25-77	2.64	3.03	5.67
06-29-77	3.03	3.50	6.53
07-29-77	3.88	3.35	7.23
08-26-77	3.06	2.65	5.71
09-17-77	4.41	3.20	7.61

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In Situ Decomposition of Roots and Rhizomes of Two Tidal Marsh Plants[1]

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ABSTRACT

In situ decomposition of roots and rhizomes of the marsh plants *Juncus roemerianus* and *Spartina cynosuroides* was investigated using the litter bag technique. The decomposition rate was greatest in the top 10 cm (20% weight loss/yr) of the marsh soil. There was no apparent decomposition below 20 cm depth. Belowground tissues of *S. cynosuroides* decomposed faster than those of *J. roemerianus* during the first four months. The rhizome decomposition rate of 27%/yr (weight loss) was faster than the 16%/yr of the roots of *J. roemerianus.* There was no difference between the decomposition rate of mixed root and rhizome materials between experiments initiated in winter and those started in the spring. This indicates a relatively constant decomposition rate during the year in the 0-10 cm soil zone. There was no apparent trend in the hydrogen, carbon, phosphorus, nitrogen, or caloric content changes of the decomposing roots and rhizomes during the study.

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INTRODUCTION

The extensive mats of roots and rhizomes produced by vascular plants in coastal marshes (Gallagher 1974; Valiela et al. 1976; Stroud 1976; de la Cruz and Hackney 1977) may be a potential source of energy and nutrients for estuarine-dependent consumers. Belowground marsh plant materials may enter the aquatic system through the digging of burrowing invertebrates, feeding and nesting activities of certain rodents and waterfowl, erosion along high energy shorelines and banks, or by seepage of dissolved substances produced by subterranean decomposition processes (de la Cruz and Hackney 1977). In an earlier publication we reported that particulate rhizospheric materials have been observed in seston samples collected from tidal creek and bayou waters in Mississippi (de la Cruz and Hackney 1977). Uprooted chunks of marsh plants may be found floating in the water or stranded on the marsh. The value of root-rhizome materials to estuarine organisms is mediated by decomposition processes that will incorporate these materials into the detritus pool. To date, there is no published information regarding the decomposition of belowground portions of vascular plants in brackish marsh soils or on the subsequent caloric and elemental changes which normally accompany decomposition. The high belowground productivity of marsh plants and the potential role they may play in the energy and nutrient fluxes in the marsh-estuary prompted this investigation.

Our objectives were to determine the in situ decomposition of dead roots and rhizomes in two tidal marsh communities and to relate these decomposition rates to corresponding caloric and elemental changes of the decomposing tissues, and to relate belowground tissue decomposition to the energetics of the marsh-estuarine system.

MATERIALS AND METHODS

The marshes studied are located on a marsh island situated on the western side of St. Louis Bay, Hancock County, Mississippi Gulf Coast. The vegetation and productivity of these marsh communities were initially described by de la Cruz (1973) and Gabriel and de la Cruz (1974). Belowground plant materials were collected from a marsh dominated by *Juncus roemerianus* in November 1976 with a sampling device 10 cm in diameter and 50 cm long. Each core was cut into 3 sections, 0-10, 10-20, and 20-30 cm, and referred to as A, B, and C. Each section was divided into quarters and the roots and rhizomes washed thoroughly, air dried to a constant weight, and placed in dry preweighed 7 x 19 cm nylon bags with 1.25 mm mesh. Thirty-five bags containing a mixture of roots and rhizomes were prepared from each of the three sections. In addition, 25 litter bags of pure root materials and 25 bags of rhizomes both collected from the 0-10 cm depth were separately prepared. The 35 litter bags containing mixed root and rhizome materials were placed below the marsh surface on 3 December 1976 by removing a 40 cm core (10 cm diameter). The core was sliced 5, 15, and 25 cm from the surface level and litter bags individually inserted into the core as follows: the A section at 5 cm, B section at 15 cm, and C section at 25 cm. The core (with litter bags) was then placed into the hole from which the original core was removed (Figure 1). The 25 litter bags containing roots and 25 containing rhizomes were buried only at the 5 cm depth followigg the same procedure. Seven mixed A, B, and C bags and 5 each of root and rhizome bags were collected approximately 1, 2, 4, 8, and 12 months after they were buried.

Additional roots and rhizomes from the *Juncus* and *Spartina* communi-

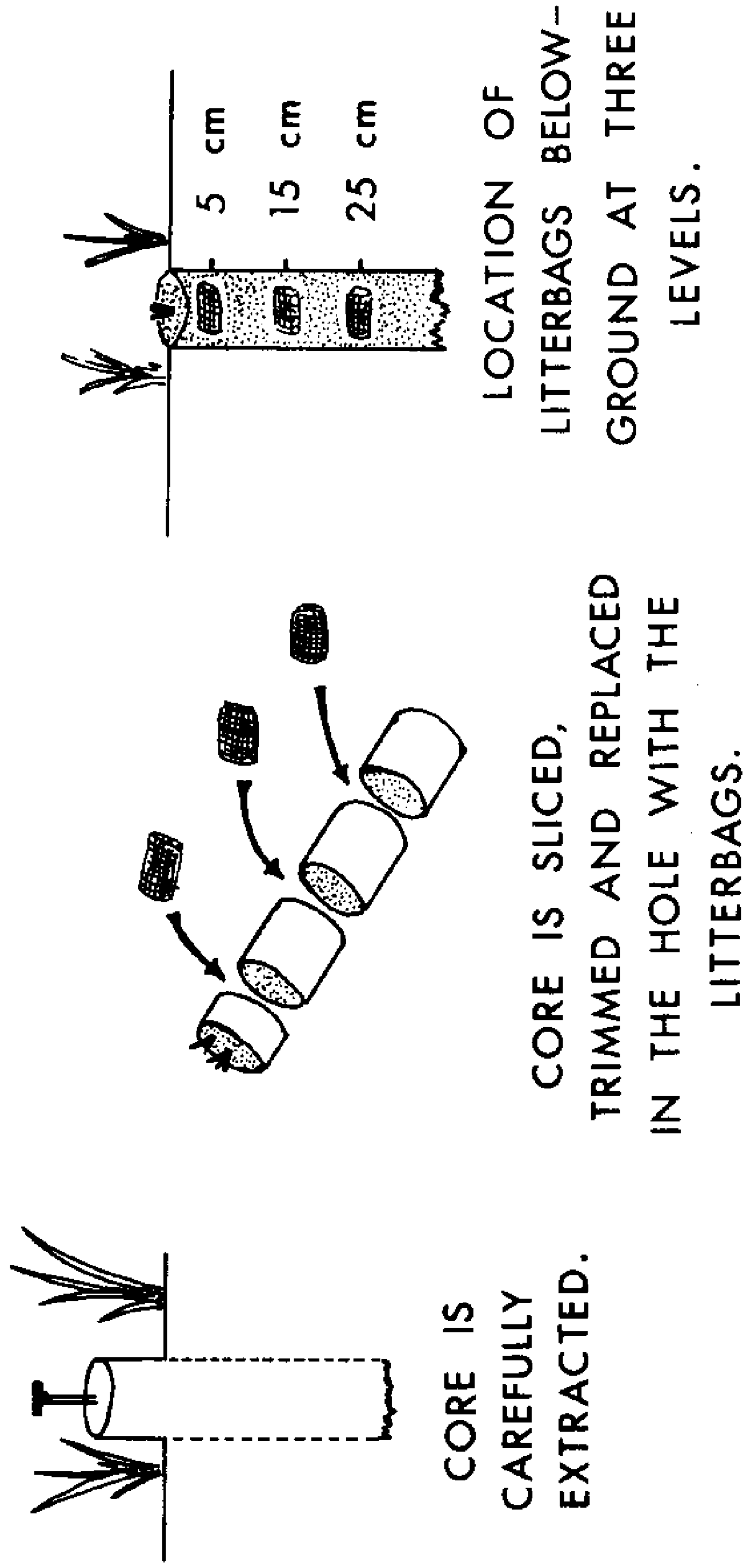

Figure 1. Illustration showing *in situ* deployment of belowground litter bags.

ties were collected in February 1977 and 48 more litter bags of mixed root-rhizomes material from the 0-10 and 10-20 cm levels of each species were prepared as before and replaced in the respective marshes on 16 March 1977. For comparison approximately 50 g of air dried dead aboveground leaves and stems were collected from the Juncus and Spartina communities, and placed in each of 48 nylon litter bags (31 x 31 cm with 3.1 mm mesh). These bags were returned to the marsh on 16 March 1977 in the same area where the belowground litter bags were located. Eight aboveground litter bags and 8 belowground bags from each of the 5 cm and 15 cm depths were retrieved from each marsh type approximately 1, 2, 4, 6, 8, and 12 months later.

All liter bags were returned to the laboratory, soaked for 24 hours in tap water and washed carefully. The bags analyzed for loss of weight were dried at 103°C and subsamples retarined for caloric and ash-free dry weight analysis. The bags analyzed for C, H, N, and P were dried at 50°C and pooled samples were ground in a Wiley-Mill ™ with a No. 60 sieve. Analyses were performed as follows: ash-free dry weight by combustion at 550°C for 6 h; energy content by combustion in a Paar Adiabatic Bomb Calorimeter Model 1214™; carbon and hydrogen by means of a Coleman C-H Analyzer Model 33™; and total nitrogen by means of a Coleman N Analyzer Model 29-021™. Total phosphorus was determined by perchloric digestion following the method outlined by Howitz (1975).

RESULTS

DECOMPOSITION RATES

Decomposition of belowground tissues was greatest at the 5 cm depth (Tables 1 and 2) for both J. roemerianus (18.0% after 382 days and 17.5%

Table 1. Mean percentage of *J. roemerianus* belowground material remianing after *in situ* decomposition initiated 3 December 1976 for different number of days. Numbers in parentheses are the standard errors.

Days in the Field	Mixed A (5 cm level)	Mixed B (15 cm level)	Mixed C (25 cm level)	Rhizomes Only (5 cm level)	Roots Only (5 cm level)
43	95.9 (1.8)	108.7 (1.8)	106.1 (4.0)	101.5 (1.2)	101.1 (1.9)
75	99.4 (1.3)	106.2 (1.2)	105.5 (1.0)	98.6 (2.1)	108.9 (5.8)
145	90.8 (3.4)	100.6 (0.8)	98.0 (1.9)	89.0 (1.6)	80.7 (1.7)
260	77.4 (1.1)	105.0 (1.8)	110.4 (2.1)	80.7 (1.5)	95.6 (2.2)
382	82.0 (5.1)	91.7 (1.8)	102.7 (3.9)	73.5 (1.1)	82.7 (4.7)

Table 2. Mean percentage of above- and belowground materials remianing after *in situ* decomposition initiated 16 March 1977 for different numbers of days. Numbers in parentheses are standard errors.

Days in the Field	*Juncus* Leaves and Stems (Surface)	*Juncus* Mixed Roots and Rhizomes 5 cm Depth	*Juncus* Mixed Roots and Rhizomes 15 cm Depth	*Spartina* Leaves and Stems (Surface)	*Spartina* Mixed Roots and Rhizomes 5 cm Depth	*Spartina* Mixed Roots and Rhizomes 15 cm Depth
42	93.5 (0.6)	91.6 (5.3)	93.4 (3.4)	97.6 (0.5)	100.9 (7.0)	104.8 (3.2)
70	86.7 (0.6)	99.5 (3.9)	107.3 (6.3)	96.1 (0.5)	97.3 (6.5)	113.4 (2.2)
134	80.0 (1.5)	88.6 (6.4)	105.6 (0.5)	89.4 (1.4)	80.2 (4.4)	93.3 (11.0)
185	62.3 (1.3)	88.1 (3.0)	104.0 (1.2)	78.2 (1.5)	71.4 (7.0)	97.0 (5.0)
253	56.9 (1.4)	85.7 (3.7)	96.5 (2.8)	74.9 (2.6)	79.7 (5.6)	93.4 (9.8)
360	52.3 (1.0)	82.5 (3.7)	92.1 (3.1)	73.9 (2.0)	79.5 (11.1)	-----

after 360 days) and S. cynosuroides (20.5% after 360 days). Decomposition rates were slower at the 15 cm level (7.9 to 8.3%/yr) and showed no weight loss until after 5 months in the J. roemerianus marsh (Tables 1 and 2). In comparison, S. cynosuroides decomposed slightly faster, 6.7% after 134 days but ramained undecomposed for the remainder of the experiment (Table 2). No decomposition of J. roemerianus belowground tissues occurred at the 25 cm depth.

Juncus rhizome materials decomposed faster (26.5%) than roots (17.3%) (Table 1). Materials deployed in winter exhibited virtually the same decomposition rate as those initially exposed in the spring (Tables 1 and 2).

Roots and rhizomes buried at the 15 cm and 25 cm levels in the J. roemerianus experiment initiated in winter gained weight (8.7 and 6.1%, respectively) after 43 days in the Marsh (Table 1). A similar phenomenon was noted in the 15 cm level of the spring experiment and also in S. cynosuroides through 70 days of exposure. There was no significant difference (α= .05) in the decomposition rates of the mixed root-rhizome material at the 5 cm depth between the two J. roemerianus experiments. Twenty-one percent of the materials collected from 0-10 cm level and buried at 5 cm depth was lost after one year in experiment 1 and 19% in experiment 2 based on predictive linear models. The rhizomes, which seemed to be the toughest material at the initiation of the experiment, decomposed faster than the roots (Figure 2). The decomposition rate of the roots and rhizomes was significantly different ($\alpha = .05_3 \times 46 = 36.16$). Based on predictive models, 16% of the pure root and 27% of the pure rhizome material decomposed after one year. The root tissues buried at 5 cm depth were still firm after 382 days while rhizomes had become

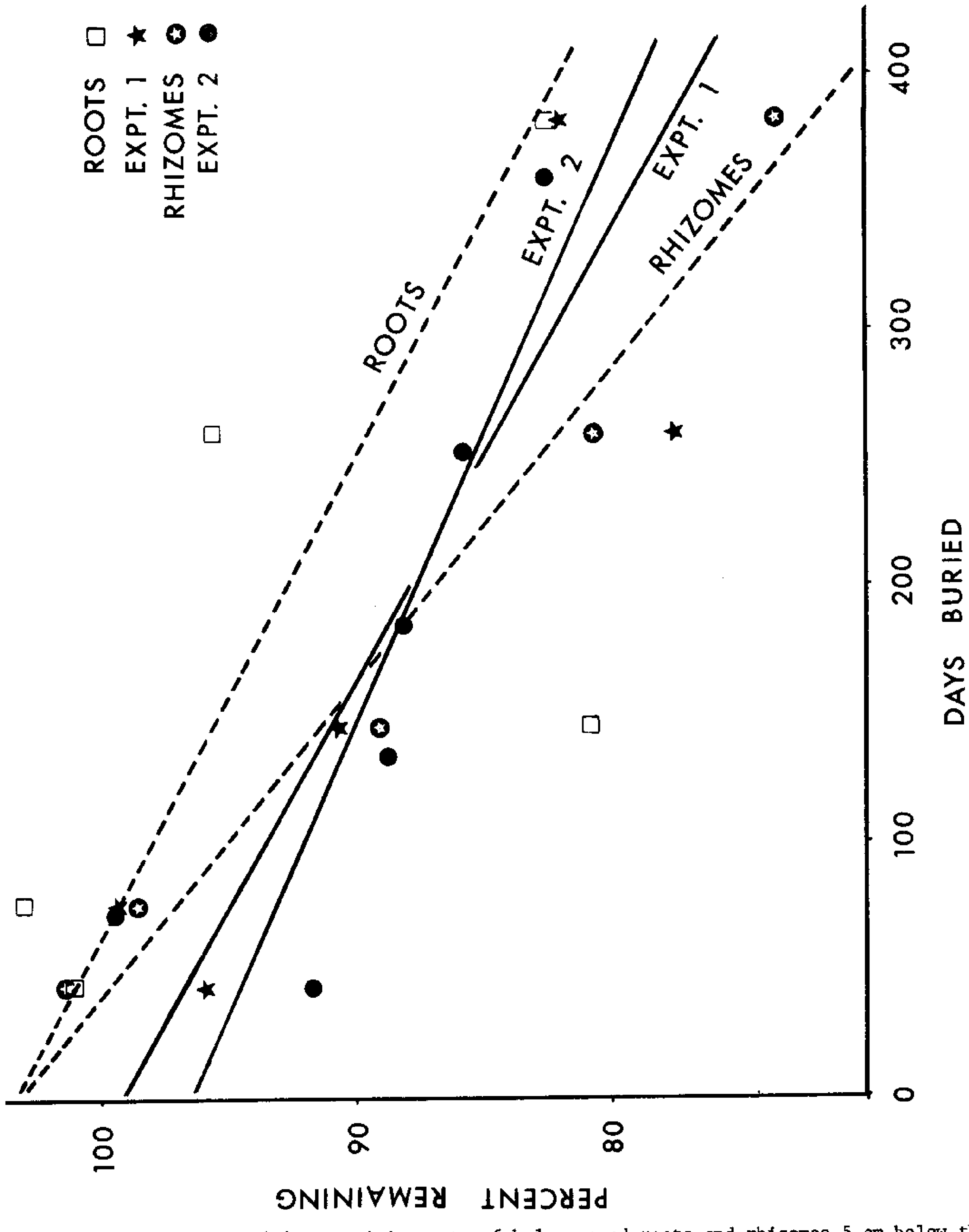

Figure 2. Predicted decomposition rate of belowground roots and rhizomes 5 cm below the marsh surface. Experiment 1 and Experiment 2 contained mixed root and rhizome materials and were initiated December 3, 1976 and March 16, 1977, respectively.

soft and flaccid. No materials in the 15 cm and 25 cm levels were visibly changed at the conclusion of either experiment.

As expected, decomposition rates of aerial plant parts were faster than those of subterranean parts. About 48% of J. roemerianus and 26% of S. cynosuroides aboveground parts decomposed after 360 days in the field. In a similar study, but using 5.0 mm mesh bags, de la Cruz and Gabriel (1974) and de la Cruz (1974) reported a 40% decomposition for Juncus and a 57% rate for S. cynosuorides, respectively. The smaller mesh bags were probably responsible for slower decomposition of S. cynosuroides shoots in the present study.

CALORIC AND ELEMENTAL ANALYSIS

There was a slight increase from day 0 in the caloric content of the decomposing aerial tissues of J. roemerianus and S. cynosuroides (Table 3). The percentages of nitrogen and phosphorus varied, but generally increased after 360 days of in situ decomposition (Table 3). The carbon and hydrogen components showed no pattern of change.

There was no discernable pattern of change with respect to any of the four elements and energy value examined for the roots and rhizomes during the 12 month period at any depth in either marsh type. Mean value for the decomposing roots and rhizomes is provided in Table 4. The elemental and caloric compositions of the decomposing roots and rhizomes were similar to those found by de la Cruz and Hackney (1977) for living roots and rhizomes. Due to lack of sufficient specimens, root and rhizome materials were not analyzed separately.

In general, the carbon content of the decomposing roots and rhizomes was lower than the decomposing leaves. The percent nitrogen, phosphorus, and hydrogen was essentially the same in the decomposing roots and rhizomes as in the decomposing leaves. Caloric content of below and

Table 3. Changes in the nitrogen (N), phosphorus (P), carbon (C), hydrogen (H), and energy contents (KJ/g AFDW) in decomposing aboveground plant material. Each value is based on three replicates of a composite sample. Two field samples formed composite samples for N, P, C, and H and six field samples composed samples for calorimetric and ash-free analyses.

Days in the Field	%N	%P	%C	%H	KJ /g AFDW
J. roemerianus					
0	0.46	0.063	46.5	6.1	18.6
43	0.41	0.065	46.2	6.3	19.3
70	0.23	0.063	43.8	6.5	19.1
134	0.21	0.064	44.0	5.9	18.3
185	0.54	0.064	46.0	6.0	19.7
253	0.56	0.064	44.5	5.9	19.9
360	0.51	0.068	44.8	5.9	19.3
S. cynosuroides					
0	0.26	0.061	45.7	5.8	18.6
43	0.26	0.059	44.9	6.0	18.6
70	0.31	0.063	42.0	6.2	19.6
134	0.24	0.063	43.7	5.9	19.0
185	0.39	0.064	44.4	5.3	19.2
253	0.32	0.064	42.4	5.2	20.2
360	0.32	0.067	45.4	6.1	19.0

Table 4. Mean nitrogen (N), phosphorus (P), carbon (C), hydrogen (H), and energy contents of KJ/g AFDW of decomposing belowground plant meterials.

Species/depth	%N	%P	%C	%H	KJ/g AFDW
Spartina cynosuroides (buried 5 cm)	0.41	0.067	37.9	5.0	19.8
Spartina cynosuroides (buried 15 cm)	0.39	0.065	40.9	5.2	19.7
Juncus roemerianus (buried 5 cm)	0.48	0.068	43.2	5.5	20.2
Juncus roemerianus (buried 15 cm)	0.45	0.067	41.5	5.4	20.9

aboveground materials was also within the same range.

DISCUSSION

The Litter Bag Technique is usually associated with aboveground decomposition studies and, with slight modification, had worked well with our belowground study. Air drying the plant material before beginning the experiment undoubtedly altered the microorganism populations of the root-rhizome material, but we considered this better than drying at 103°C and altering some of the chemical constituents of the plant material. A conversion factor was then necessary to convert air dried weight to oven weight at 103°C and may have contributed to the variability between litter bags containing mixtures of roots and rhizomes. There was less variability between bags containing pure root or pure rhizome materials.

We found it impossible to remove a core of soil without causing some disruption of the soil community and noted that the characteristic color and odor of the soil did not return until our second collection (after 2 months). The return to normal soil conditions may be due to the penetration of the disturbed soil by new roots, especially at the 5 cm and 15 cm depths. Another difficulty was the penetration of the litter bags by new roots after eight months. In the samples buried 382 days, removal of the new root growth from the litter bags proved to be difficult. While we feel that we were successful in removing 95% of the newly grown roots, the invasion of new roots into the litter bags might render longer studies inaccurate. It was not possible to separate completely dead roots and rhizomes from live tissues; thus, the materials enclosed in the litter bags were a mixture of dead and living materials. Ideally, one would use recently dead roots and rhizomes, following the procedures normally applied in aboveground decomposition studies.

De la Cruz and Hackney (1977) found that the belowground productivity of the Juncus marsh was 1.36 kg/m^2/yr and suggested that the productivity was probably higher since the technique used to estimate productivity ignored loss by decomposition. The slow decomposition rate of belowground materials suggests that even if all of the decomposition occurred at the time of peak biomass (i.e., during May-June) there would be no increase in the productivity 20-30 cm below the marsh surface and only an 8% increase in the 0.60 kg/m^2/yr produced in the 10-20 cm depth. There would be about 20% increase in the top 10 cm of the marsh substrate. Our predictive linear models of the decomposition in the 0-10 cm level suggest that the decomposition rate is relatively constant during the year since the early winter study and the early spring study had the same decomposition rate at the 0-10 cm level.

The live and dead plant tissues present in the top 40 cm of the marsh soil ranged from 9.7 -12.4 kg/m^2 (de la Cruz and Hackney 1977). Eleuterius (1975) estimated that one third of the rhizomes of J. roemerianus are replaced by new growth each year. Thus, based on the productivity previously estimated (de la Cruz and Hackney 1977) only about 4.0 kg/m^2 of the belowground plant material is alive at any one time. The loss of plant material by decomposition can be considered constant which would not change the 1.36 kg/m^2/yr productivity estimate. Because the belowground standing biomass returned to about the same level after one year, de la Cruz and Hackney (1977) suggested a higher decomposition rate than we found in this study. Apparently there is not peat formation in the upper levels of the marsh (Hackney and de la Cruz 1978) since surface organic content of the marsh soil remains constant due to the continuous addition of organic and inorganic materials from terrestrial overflow. During one year of actual measurements of suspended material transport, we found that this addition amounted to 168 g/m^2 (Hackney and de la Cruz, In Press). This suggests that our earlier hypothesis was true (de la Cruz and Hackney 1977) i.e., that dead root and rhizome material is constantly being buried. Enough inorganic sediment is being added to maintain a marsh soil relatively low in organic content. The addition of roots and rhizomes to the marsh soil is greatest in the 10-20 cm level where the root-rhizome productivity is high and where the decomposition is low. Thus, the marsh is actually growing from below the marsh surface.

The biomass of roots and rhizomes in the upper 20 cm of the *S. cynosuroides* marsh is high, 10.9 kg/m^2 (de la Cruz and Hackney 1977). The roots are particularly dense in the upper 10 cm where they are frequently found covering the surface of the marsh. This may be in response to nutrient availability. Because *Spartina* species are known to pump oxygen down into the soil through their roots (Van Raalte 1940; Waisel 1972), we expected their roots and rhizomes to decompose faster than the *Juncus*, since Reddy and Patrick (1975) found a greater decomposition rate in aerobic versus anaerobic soils. Low subsurface decompositions rates were reported for freshwater marshes (Heal, Latter and Howson 1978). Martin and Holding (1978) suggested that this decreased decomposition rate was not only due to the aerobic conditions, but was caused by the slower heating of waterlogged soils and the lack of macerating organisms in the soil. Differences between the decomposition rates of the two species may also be affected by texture and fiber strength of the rhizospheric tissues.

The root-rhizome material gained weight after the initiation of all experiments in the 15 and 25 cm depths. There was still more than 100% of the original material by weight after 382 days in the 25 cm level (Table 1). The same phenomenon was observed by Stout (pers. comm.) in a J. roemerianus and in a Spartina alterniflora marsh on Dauphin Island, Alabama. We suggest that there may be a process of mineralization occurring in the 15 and 25 cm levels. Indeed, Howarth (1978) found that iron pyrite forms rapidly in anaerobic salt marsh soils and that as much as 90% of the labeled sulfur he introduced into these soils was converted into iron pyrite that was eventually associated with organic matter. This phenomemon deserves attention.

Traditional studies of the decomposition of aerial portions of marsh plants usually reveal an increased nitrogen content (de la Cruz 1973). Decomposition rates of the aerial portions were also similar to those reported earlier (de la Cruz 1973). The absence of apparent trends in the nitrogen, phosphorus, carbon, hydrogen or the energy value of either species of root-rhizome material at either the 5 or 15 cm depths indicates that either the microbial populations are constant or that the normal elemental changes associated with decomposition require a longer period of time to become obvious. The lack of any significant changes of these elements further substantiates the very slow decomposition rates of roots and rhizomes in marsh soils. In waterlogged soils, decomposition a few centimeters below the surface is extremely slow due to anaerobic conditions (Clymo 1965; Reddy and Patrick 1975). The large biomass of decaying plant material present belowground and the relatively undiminished nutritive value of this material mean that there is a stable, highly nutritious energy supply available for organisms which may be able to utilize such a source.

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In Situ Decomposition of Dead Tissues of Selected Tidal Marsh Plants[1]

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ABSTRACT

Recognition of salt marsh plant detritus as a source of energy and nutrient for estuarine animals prompted investigation of *in situ* decomposition and elemental analyses of four plants at various stages of decay, namely: *Spartina alterniflora*, *Juncus roemerianus*, *Distichlis spicata*, and *Spartina patens*, commonly growing in Alabama and Mississippi Gulf coasts. Annual decomposition of aboveground material for these four plants were 86, 44, 38, and 36% respectively. There was a general decrease in carbon and hydrogen, and a slight increase in nitrogen, phosphorus and caloric content of aboveground tissue during decomposition.

Annual loss of belowground biomass due to decomposition was most consitent with depth for *J. roemerianus*, losing 25% in the upper 10 cm and 22% at depths of 11-20 cm. The greatest belowground loss of 31% was for *S. alterniflora* at the 11-20 cm depth with only 14% loss in the upper 10 cm. Decomposing belowground material did not exhibit any discernable patterns of change in tissue nutrient or caloric content.

INTRODUCTION

A common biological feature of tidal marshes is high primary productivity which supports coastal marine fisheries. The link between marshland organic productivity and marine fertile fisheries is the complex interaction of decomposition processes and transport mechanisms that make energy and nutrients produced on the marsh available to marine consumers. Initial to this important ecosystem coupling of marsh and estuary is the breakdown of abundant plant matter into particulate detritus. In this paper, we examined the decomposition to particulate detritus of 4 species (smooth cordgrass, *Spartina alterniflora*; black needlerush, *Juncus roemerianus*; salt grass, *Distichlis spicata*; and wire grass *Spartina patens*) of vascular plants common in the Mississippi-Alabama coastal marsh. To simulate natural conditions under which decomposition takes place, dead plant shoots which were about to fall on the ground were collected in early winter and root and rhizomes extracted from the marsh substrate, that appeared to be dead, were used in the experiment. To determine nutritive changes in the decomposing plant tissues, ash-free weight, caloric content, and carbon, hydrogen, nitrogen and phosphorus concentrations were analyzed. Previous reports (e.g. Gabriel and de la Cruz 1974; de la Cruz 1975) have shown that there is a retention of and/or increases in, nutritional quality of the decomposing detritus.

MATERIALS AND METHODS

In situ decomposition of dead plant materials was determined by means of the litterbag technique commonly employed in this type of study.

Dead aboveground materials were collected from the four marsh communities, air dried, and approximately 50 grams was placed in each of 48 nylon-mesh litterbags (31 x 31 cm; 3.1 mm mesh). These bags were deployed on the marsh in the same area and time as the belowground litterbags. Sets of 4 litterbags were retrieved from each marsh type approximately 1, 2, 4, 6, 8, and 12 months later. Three of the bags were processed for dry weight, ash-free dry weight and caloric determinations; the remaining bag was processed for microbial analysis and for elemental contents.

Belowground material was collected with a coring device (Figure 1) from S. alterniflora and J. roemerianus communities in February 1977. Each core was cut into 2 sections, 0-10 and 11-20 cm and are referred to as sections A and B, respectively. Each section was divided into vertical quarters and the mud washed off thoroughly removing all fine silt and clay particles. The washed material was air dried to a constant weight and placed in tared 7 x 10 cm nylon bags (1.25 mm mesh). Twenty-four litterbags were prepared from the A section and twenty-four from the B level in each marsh type with approximately 10 grams of root-rhizome material placed in each bag. Extra samples of the original material were retained for elemental, caloric and ash-free weights to the equivalent weight at 103^{o} C. A separate conversion factor was obtained for each species and for each core section. The litterbags were deployed on the marsh in March, 1977. The bags were placed below the marsh surface by digging a hole with the coring device originally used to collect the samples. The extracted core was cut at the 5 and 15 cm levels and a bag containing material originally collected from the A and B levels were placed in the 5 and 15 cm

Figure 1. A. Core sampler used to collect belowground materials.
B. Core samples serially cut into 10 cm sections on the marsh.

depth, respectively, according to the method devised by Hackney and de la Cruz (In press). The 15 cm long core material separated the A and B bags and the 5 cm long core plugged the top of the original hole.

After approximately 1, 2, 5, 6, 3, and 12 months the litter bags were recovered from the field - four bags from A level and four from B level. Three of the 4 bags were returned to the laboratory, soaked for 24 hours in tap water, washed very carefully so as not to fractionate any decomposed material, dried at 103° C and reweighed. A homogeneous sample of this material was retained for caloric and ash-free weight analysis. The remaining one bag was carefully placed in sterile plastic bags in the field and analyzed for bacteria and fungi (results reported in Part III of this volume). The unused material from this bag was later dried at 50° C and analyzed for C, H, N, and P contents.

All samples for elemental, caloric and ash-free weight analyses were ground in a Wiley-Mill with a No. 60 sieve. Samples were analyzed as follows: ash-free dry weight by combustion at 550° C for 6 h; energy content by combustion in a Paar Adiabatic Bomb Calorimeter Model 1214; carbon and hydrogen by means of a Coleman C-H Analyzer Model 33; and nitrogen by means of a Coleman N Analyzer Model 29-021. Total phosphorous was determined according to the method outlined by Howitz (1975).

RESULTS AND DISCUSSION

Decomposition. Figure 2 summarizes the dynamics of aboveground decomposition of *J. roemerianus*, *S. alterniflora*, *D. spicata*, and *S. patens*. *S. alterniflora* decomposed most rapidly, approximately 75% lost by the end of 66 days, and most completely with only 14% of the original material remaining after one year (364 days). Juncus roemerianus decayed much more slowly at a fairly constant rate (Figure 2). Over 56% of the dead J. roemerianus material remained after one year of decomposition, very similar to the same species studied simultaneously in Mississippi. Differences between these two species can be attributed both to differences in stem tissue fiber and environmental conditions of the typical habitat of each. Decomposition would be expected to be more rapid in the moist intertidal habitat of S. alterniflora and this species has much less fibrous stems and leaves than J. roemerianus. The decomposition of S. patens which was slow and gradual, amounted to about 36% per year. Total litterbag weight in the D. spicata environment is extremely variable being quickly influenced by rainfall or drought conditions. Changes in litterbag contents during the earlier portion of the year may reflect massive colonization of the bags and their contents by benthic organisms with a subsequent decline in population size accompanying a slow, gradual decay process.

Belowground decompositiom at both the 0-10 cm and 11-20 cm depths was very slow for J. roemerianus and S. alterniflora. Both demonstrated irregular increases in litterbag contents following initial declines at both depth levels. Greatest loss in one year was at the 11-20 cm in S. alterniflora in which 69.1% of original material remained. Decomposition within the upper 10 cm of S. alterniflora was lowest with only 13.8% lost over the year (Figure 3). J. roemerianus demonstrated greater decomposition in Alabama than in Mississippi losing 25.2% and 22.0% in the 0-10 cm and 11-20 cm portions respectively (Figure 3) as compared to 17.5 and 7.9% respectively in Mississippi.

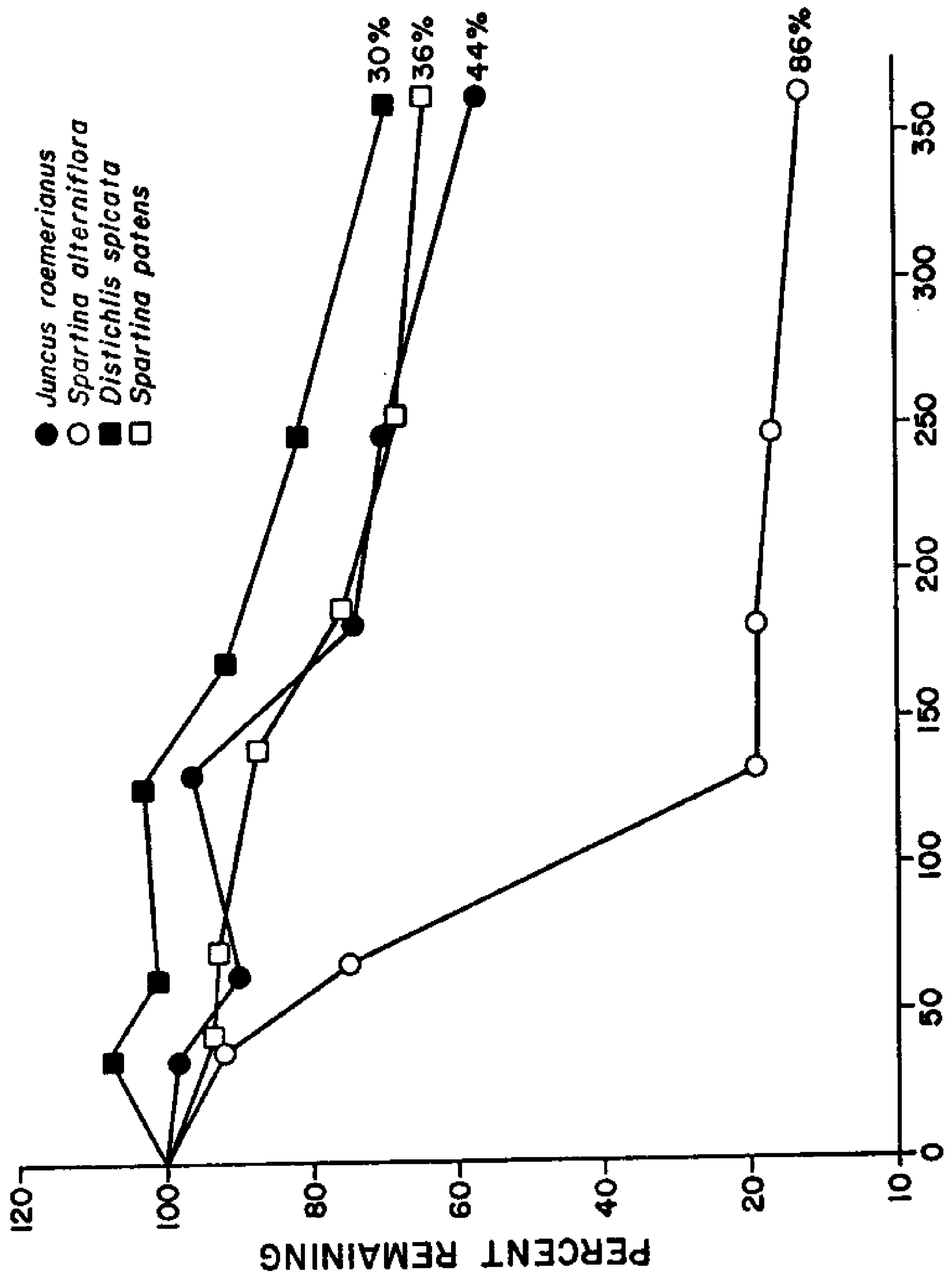

Figure 2. The decomposition of the dead aboveground parts (shoots and stems) of J. roemerianus, S. alterniflora, Distichlis spicata and S. patens.

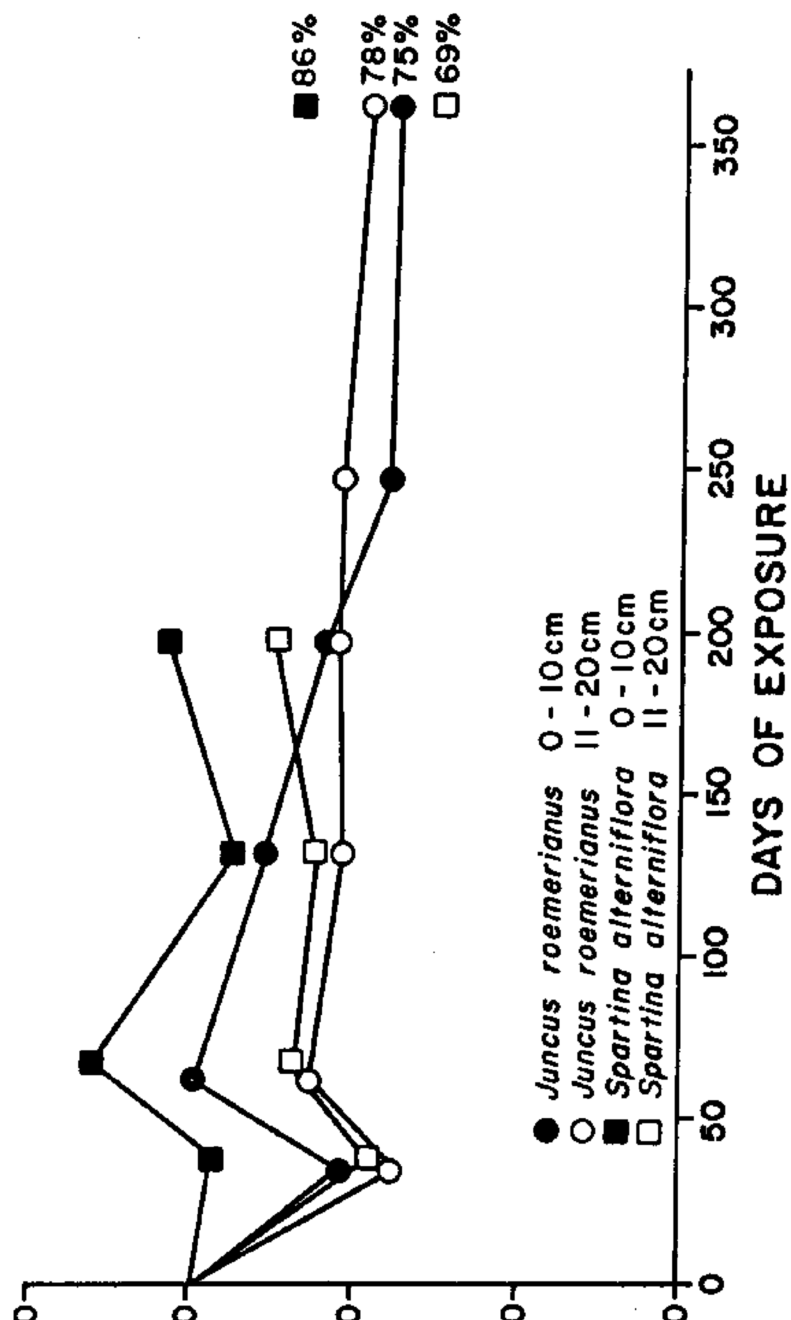

Figure 3. Belowground decomposition at 0-10 cm and 11-20 cm levels in the Alabama J. roemerianus and S. alterniflora communities.

Nutrient Analyses. There was slight increases in the energy content of the decomposing aboveground materials during the study (Tables 1-3). The percentage of carbon in the decomposing tissues generally decreased except in *S. patens*. The percentage of nitrogen and phosphorous was high in the early stages of decomposition or was low, but in either case there was a marked increase after 360 days of decomposition except in *S. alterniflora*.

Decomposing belowground materials did not reveal any discernable patterns of change with respect to the nitrogen, phosphorous, carbon, hydrogen and caloric composition (Tables 1-3). Most values were similar to those previously reported by de la Cruz and Hackney (1977) for the standing crop of root and rhizome materials.

Table 1. Carbon (c), hydrogen (H), nitrogen (N), phosphorous (P) and energy contents (Kcal/gAFDW) of decomposing aboveground and belowground materials from the 0-10 cm and 11-20 cm levels of *Spartina alterniflora*.

No. Days Exposed	%C	%H	%N	%P	Kcal/gAFDW
			Aboveground Leaves		
0	38.772	5.530	0.810	0.839	4.521
39	44.625	5.950	0.414	0.064	-
66	41.858	6.022	0.470	0.065	4.550
132	39.396	5.729	0.451	0.069	4.739
181	35.854	5.206	0.607	0.071	5.035
247	35.855	5.110	0.600	0.076	-
364	37.010	4.812	0.611	0.075	-
			Belowground Roots and Rhizomes at 0-10 cm Level		
39	41.468	5.425	0.772	0.067	-
66	39.440	5.269	0.726	0.067	4.928
132	33.286	4.851	0.626	0.071	4.795
181	35.554	5.083	0.563	0.071	4.994
247	-	-	-	-	-
364	37.202	5.210	0.581	0.072	-
			Belowground Roots and Rhizomes at 11-20 cm Level		
39	38.876	4.990	0.838	0.067	-
66	34.683	4.371	0.639	0.063	5.310
132	32.469	3.993	0.583	0.067	5.312
181	34.467	4.785	0.548	0.074	4.909
247	-	-	-	-	-
364	36.311	5.187	0.527	0.070	-

Table 2. Carbon (C), hydrogen (H), nitrogen (N), phosphorous (P), and energy contents (Kcal/gAFDW) of decomposing aboveground and belowground materials from the 0-10 cm and 11-20 cm levels of *Juncus roemerianus*.

No. Days Exposed	%C	%H	%N	%P	Kcal/gAFDW
			Aboveground Leaves		
0	45.042	6.251	0.380	0.064	4.592
34	45.329	6.446	0.304	0.619	-
63	45.758	6.055	0.323	0.066	4.638
132	42.435	5.942	0.210	0.060	4.583
182	40.469	5.401	0.639	0.064	4.720
247	42.330	5.399	0.494	0.066	-
363	41.084	5.081	0.543	0.070	-
			Belowground Roots and Rhizomes at 0-10 cm Level		
34	41.003	5.063	0.587	0.067	-
63	36.565	4.926	0.314	0.064	4.997
132	39.026	5.062	0.549	0.073	4.879
182	35.463	4.733	0.500	0.070	4.689
247	38.992	4.861	0.564	0.071	-
363	36.428	4.719	0.604	0.072	-
			Belowground Roots and Rhizomes at 11-20 cm Level		
34	43.668	5.204	0.662	0.066	-
63	37.739	4.970	0.446	0.059	4.173
132	40.229	5.037	0.602	0.072	5.193
182	37.061	4.819	0.623	0.696	5.337
247	36.997	4.849	0.607	0.072	-
363	37.262	4.793	0.565	0.071	-

Table 3. Carbon (C), hydrogen (H), nitrogen (N), phosphorus (P), and energy contents (Kcal/gAFDW) of decomposing aboveground materials of *D. spicata*.

No. Days Exposed	%C	%H	%N	%P	Kcal/gAFDW
			Aboveground Leaves		
0	-	-	-	-	4.526
37	44.234	6.142	0.373	0.066	4.627
64	44.675	6.253	0.230	0.065	4.737
126	41.798	5.634	0.379	0.062	4.831
170	37.368	4.832	0.428	0.066	-
360	37.922	5.096	0.397	0.064	-

Table 4. Nitrogen (N), phosphorus (P), carbon (C), hydrogen (H), and energy contents (Kcal/gAFDW) of decomposing aboveground materials of *S. patens*.

No. Days Exposed	%C	%H	%N	%P	Kcal/gAFDW
			Aboveground Leaves and Stems		
0	45.583	6.016	0.321	0.066	4.600
42	44.462	5.834	0.230	0.063	4.602
70	46.597	6.155	0.360	0.067	4.651
135	45.560	6.026	0.240	0.066	4.613
185	44.782	5.593	0.440	0.072	4.634
286	44.873	5.716	0.464	0.068	4.880
391	45.725	6.148	0.442	0.071	4.615

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Aboveground Net Primary Productivity of Three Gulf Coast Marsh Macrophytes in Artificially Fertilized Plots

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ABSTRACT

Plot (100 m^2) of four tidal marsh communities (Juncus roemerianus and Spartina alterniflora in Alabama, J. roemerianus and Spartina cynosuroides in Mississippi) common in the Gulf Coast were enriched with commercial NH_4NO_3 (34% N). The fertilizer was applied once at the beginning of the 1978 growing season to simulate a farm-plantation operation at a dosage (136 g/m^2) estimated to return to the soil approximately the same amount of nitrogen contained in the plants. Six 0.25 m^2 quadrats were harvested monthly from each community from April through November. The annual net productivity was estimated with a maximum minus minimum standing crop technique based on a predictive periodic model (PPM). A correction for plant mortality during the sampling period is provided in the PPM technique. Annual aboveground net primary productivity increased by 59% in the Alabama J. roemerianus, 74% in the Mississippi J. roemerianus, 82% in the S. alterniflora and 24% in the S. cynosuroides. It appears that short form or high marsh macrophytes responded more to nitrogen enrichment than tall form or low marsh plants.

Running Head: Productivity of Fertilized *Juncus* and *Spartina* Marshes.

Key Words: Marsh fertilization, primary productivity, *Juncus roemerianus*, *Spartina alterniflora*, *Spartina cynosuroides*, Alabama, Mississippi, Gulf Coast.

INTRODUCTION

Experimental enrichment of marshes with nitrogen fertilizer has resulted in a dramatic increment in biomass production (1), (2), (4), (10), (12), (14) indicating the role of nitrogen as a limiting factor in the growth of marsh plants. Repeated fertilization of a S. alterniflora (short form) marsh in Delaware with commercial grade ammonium nitrate at 20 g/m^2 increased biomass production by at least 100% (14). A study done on a Juncus gerardi marsh in Sweden (15) showed 30% biomass increase following a single application of nitrogen as ammonium chloride. Fertilization studies conducted on S. alterniflora and S. patens marshes in Massachusetts using urea and commercially available sludge also resulted in increased productivity (16). Similarly, studies on both natural and artificially propogated S. alterniflora in North Carolina showed that the addition of nitrogen as ammonium sulfate doubled the yield of aboveground shoots (1). But, an enrichment study on marsh communities similar to the ones fertilized in the present study treated with 13-13-13 (n-P-potash) fertilizer at the recommended single dosage of 71 g/m^2 (9.2 g N/m^2) did not change the annual biomass yield of the plants (13). Nitrogen in the ammonium form promotes better growth than nitrate nitrogen (10).

Our current investigations of management procudures applicable to coastal wetlands for purposes of cultural activities promoted our interest in artificial enrichment of marshes. Development of certain marshlands into farm-plantations fro cropping marsh grass is likely, should our attempts to recover chemicals of potential pharmacological value and by-products relative to extraction of pulp from marsh vegetations prove feasible. In either case, harvesting marshland meadows for products of direct value to mankind implies a cropping system that will produce maximum biomass yield. Obviously, any cultural use of a marsh will likely be done on the high marsh through fertilization, especially of high elevation areas which are the marsh type most likely to be altered.

The objective of this effort was to determine the effect of a commercial fertilizer (NH_4NO_3) on the annual biomass yield of marsh plants common to the north central Gulf Coast when applied once at the beginning of the growing season.

MATERIALS AND METHODS

Four marsh communities were studied: a *Juncus roemerianus* and a *Spartina cynosuroides* marshes in Mississippi and a *J. roemerianus* and *S. alterniflora* marshes in Alabama. The *J. roemerianus* communities were both short-medium forms (about 1.0 m in height), although the *J. roemerianus* in Mississippi is more of a high marsh community than the one in Alabama. The *S. alterniflora* community was an inland high marsh with short (0.5 m) plants while the *S. cynosuroides* was the typical giant cordgrass community growing to about 2-3 m in height. The substrates of the two Alabama marshes are of higher salinity, higher sand content, and lower organic matter concentration. The tide ranges in the Alabama and Mississippi marshes are similar. However, the degree and frequency of inundation are different due to topographic differences. The *S. alterniflora* marsh is regularly and completely inundated. The *J. roemerianus* marsh in Alabama has a lower profile than the one in Mississippi and thus, more frequently inundated.

Two 100 m^2 plots were established in each of the marsh communities. One of the two plots in each marsh type was used as a control plot. The other plot was enriched with commercial ammonium nitrate (34% N) fertilizer at the rate of 136 g/m^2 which is about five times the recommended per area dosage of 25 g/m^2 for normal lawn-farm treatment in Mississippi and Alabama. The fertilizer was applied in mid-February 1978 when the marsh was beginning its annual spring regrowth. A single application of fertilizer was adhered to in compliance with common practice and for economy. To make our results comparable with results of another study whereby enrichment was caused by ashes remianing after the marsh is burned, 136 g/m^2 of NH_4NO_3 (34% N) was applied. This dosage was estimated to return to the soil the same amount of nitrogen contained in the plant shoots above a square meter area, and was intended to simulate a post fire condition. The fertilizer was applied by hand broadcast during low tide as soon as the marshes became exposed. Tides along the north central Gulf Coast region are mostly diurnal so that there was at least 24 hr before the next high tide. During the month of February, northerly winds predominate and the marshes in Mississippi were seldom flooded. The fertilizer had adequate time to become incorporated into the moist mud.

Six 0.25 m^2 quadrats were harvested monthly from the control and from the fertilized plots of each marsh community from April through November. The samples were sorted into dead or living plants, dried at 100°C to constant weight and weighed. Dead and decaying litter on the ground was also collected in the Mississippi marshes but not in Alabama where the marsh floor was almost always virtually free of litter. The marshes in Alabama were monospecific while a few associated monir species were found in the Mississippi marshes.

The annual net aboveground primary productivity (NAPP) was estimated from changes in standing biomass using a maximum minus minimum technique based on a predictive periodic model (PPM) devised by Hackney and Hackney (5). The PPM fits a periodic regression curve of:

$$h = a_o + a_1 \sin (cti) + a_2 \cos (cti) + a_3 \sin (2\ cti) + a_4 \cos (2\ cti),$$

where $c = 2\ \P/n$,

$ti = 1$ to 9,

a_o = overall mean,

a_1 and a_2 are coefficients of the first harmonic term, and

a_3 and a_4 are coefficients fo the second harmonic term,

to the total biomass. Productivity was calculated by subtracting the minimum expected value of standing biomass in winter from the maximum expected value of standing biomass in summer. The NAPP was corrected for die-back or loss due to plants dying during the intervals between sampling periods according to the PPM method (5). This involved the analysis of the monthly standing dead biomass from another plot previously cleared of all plant material and the periodic max-min value obtained was added to the control and fertilized data for each marsh community.

RESULTS AND DISCUSSION

The annual aboveground net primary productivity of the control (i.e., natural) and experimental (i.e., fertilized) plots is summarized in Table 1. Fertilization with NH_4NO_3 significantly increased primary productivity by 74% for Mississippi J. roemerianus, 59% for Alabama J. roemerianus, 82% for S. alterniflora and 24% for S. cynosuroides. With the exception of S. cynosuroides, the increase in primary productivity in the fertilized plots were statistically significant from the control in the means and/or harmonic components fo the periodic model (Table 2). Table 2 shows the summary of the PPM statistics. With the exception of the two Juncus control plots, all r^2 values were significant. Due to the growth pattern of J. roemerianus in Mississippi (Figure 1), a four-harmonic equation was used for this marsh community.

The net aboveground primary productivity of 333-763 $g/m^2/yr$ for the control J. roemerianus in Alabama and Mississippi is comparable to the values reported for a high marsh J. gerardi (616 g/m^2) in Maine (9) and a high marsh J. roemerianus (595 $g/m^2/yr$) in north Florida (8). The 621 $g/m^2/yr$ NAPP for the control S. alterniflora is comparable to the data obtained for inland marsh (581 $g/m^2/yr$) in Barataria Bay, Louisiana (7). The 2324 g/m^2 annual NAPP of S. cynosuroides was close to the 2190 g/m^2 previously determined for a similar marsh (3). The productivity values obtained for the fertilized plots, while they were significantly higher than that of the control (Table 2), nevertheless fall within the maximum ranges of values reported earlier (6), (9), (17) for natural marshes from different geographic regions although different methods of determination NAPP were used.

In this study, a comparison was made between a natural marsh and a marsh which received N enrichment, in the form of NH_4NO_3. Comparing our observations with those made earlier by other investigators (1), (14), (15) it appears that N enrichemnt in the form of ammonium is better utilized by marsh plants than if the N is in the NO_3 form (10), (11), (13).

As can be seen in Figures 1 and 2, the standing crop of live plants in the fertilized plots were higher than the control from May to the end of the growing season (October-November) in all four marsh communities. The growth patterns of J. romerianus in Mississippi during the 1978 growing season showed two growth peaks, in June and October, as reflected by the two-harmonic curves in the periodic model (Figure 1). It appears that there is a high Juncus die-back during the months of July and August as indicated by the high biomass of standing dead plants during these months. Unlike the Mississippi marsh, the Alabama J. roemerianus marsh did not show a bimodal growth pattern (Figure 1). Standing crop peaked only in September. NAPP of the Mississippi Juncus community is more than twice that of Alabama for both control and fertilized plots. The growth curves (Figure 2) for the two Spartina species generally followed the same pattern with peak biomass in August. The monthly standing crop of S. cynosuroides was twice that of S. alterniflora in both control and fertilized plots. Productivity values of S. cynosuroides was 120% (in the control) and 118% (in the fertilized plot) more than that of S. alterniflora.

The data presented in Table 1 and Figures 1 and 2 do not indicate any variability because they are derived from the predictive model. There was variability among the six replicates collected monthly from each marsh community. Standard deviations of ± 200 g/m^2 was observed in the maximum raw values during peak biomass production of Spartina spp. and ± 50 g/m^2 in the minimum raw data at the beginning of the growing season of Juncus.

The higher response of the high marsh J. roemerianus (74%) in Mississippi and of the short form S. alterniflora (82%) to fertilization compared to the low marsh J. roemerianus (59%) in the Alabama and the giant cordgrass S. cynosuroides (24%) indicated that there may be a differential reaction of different growth forms of marsh plants to nitrogen enrichment. A study in North Carolina (10, 11) showed that nitrogen fertilization increased the aerial standing crop of the short form of S. alterniflora as much as 172%, but had no significant effect on that of the tall form. These observations suggest that marsh management by fertilization is most applicable to high marsh areas because of suitable hydrology and the potentially higher biomass production increment of the plant types that grow there.

Table 1. Summary of annual net aboveground primary productivity of four marsh communities which received a single application (136 g/m^2) of commercial ammonium nitrate (24% N) fertilizer.

	Net Aboveground Primary Productivity ($g/m^2/yr$)					
	Control			Fertilized		
Marsh Community	Live[1]	Dead[2]	Total	Live[1]	Dead[2]	Total
Juncus roemerianus (Mississippi)	549	214	763	1191	214	1405
J. roemerianus (Alabama)	253	80	333	449	80	529
Spartina alterniflora	441	180	621	948	180	1128
S. cynosuroides	1766	558	2324	2369	558	2927

[1]Periodic max-min values derived from Figures 1 and 2.

[2]Values based on PPM analysis of monthly standing dead biomass collected from a clipped plot previously cleared of all plant material.

Table 2. Periodic models and summary statistics for the four marsh communities.

Juncus (Miss) $y = c_0 + c_1 \sin(cti) + c_2 \cos(cti) + c_1 \sin(2cti) + c_2 \cos(2cti)$

Others $y = c_0 + c_1 \sin(cti) + c_2 \cos(cti)$

Marsh Type	c_0	c_1	c_2	c_3	c_4	r^2
J. roemerianus control (MS)	858.3	-209.0	-54.7	-106.6	33.3	.373
J. roemerianus fertilized (MS)	1092.8	-400.1	35.3	-217.6	199.0	.548*
J. roemerianus control (AL)	129.8	-17.6	26.4	--	--	.208
J. roemerianus fertilized (AL)	133.8	-55.5	-13.6	--	--	.515*
S. alterniflora control (MS)	107.2	-52.6	19.7	--	--	.720*
S. alterniflora fertilized (MS)	136.5	-118.6	-19.2	--	--	.780*
S. cynosuroides control (AL)	847.1	-764.6	-441.5	--	--	.750*
S. cynosuroides fertilized (AL)	957.5	-1018.5	-605.2	--	--	.690*

Comparisons between control and fertilized	c_0	c_1	c_2	c_3	c_4
J. roemerianus control vs. fertilized (MS)	*	--	--	N.S.	N.S.
J. roemerianus control vs. fertilized (AL)	N.S.	*	*	--	--
S. alterniflora control vs. fertilized (MS)	*	*	N.S.	--	--
S. cynosuroides control vs. fertilized (MS)	N.S.	N.S.	N.S.	--	--

* = Significant at 0.05.

N.S. = Not significant.

Significance of c_o indicates a significant difference in the means, c_1, the first harmonic component, c_2, the second harmonic component, c_3, the 3rd harmonic component, and c_4, the 4th harmonic component.

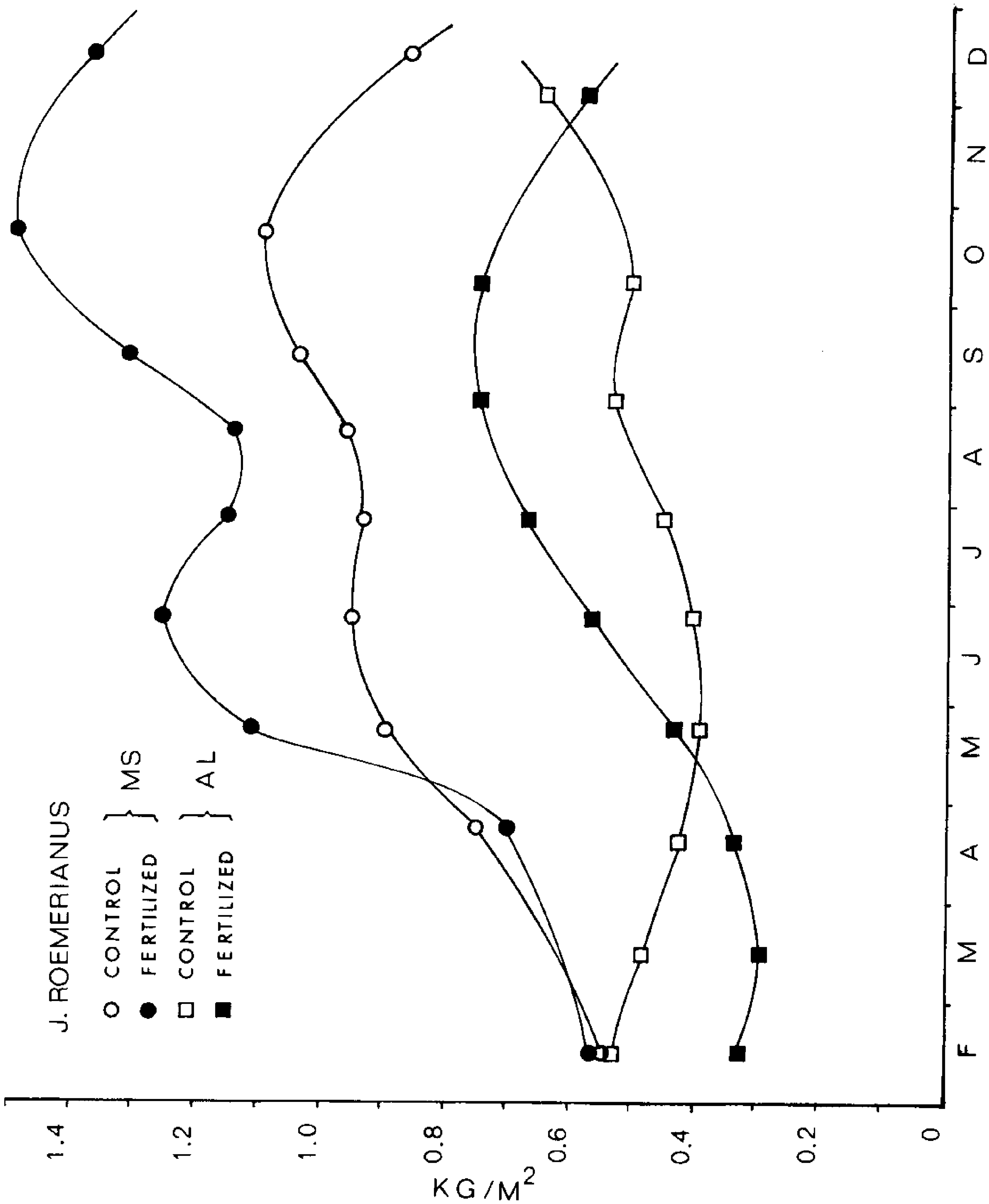

Figure 1. Periodic max-min curves for Mississippi and Alabama Juncus roemerianus based on on monthly standing crop of live plants.

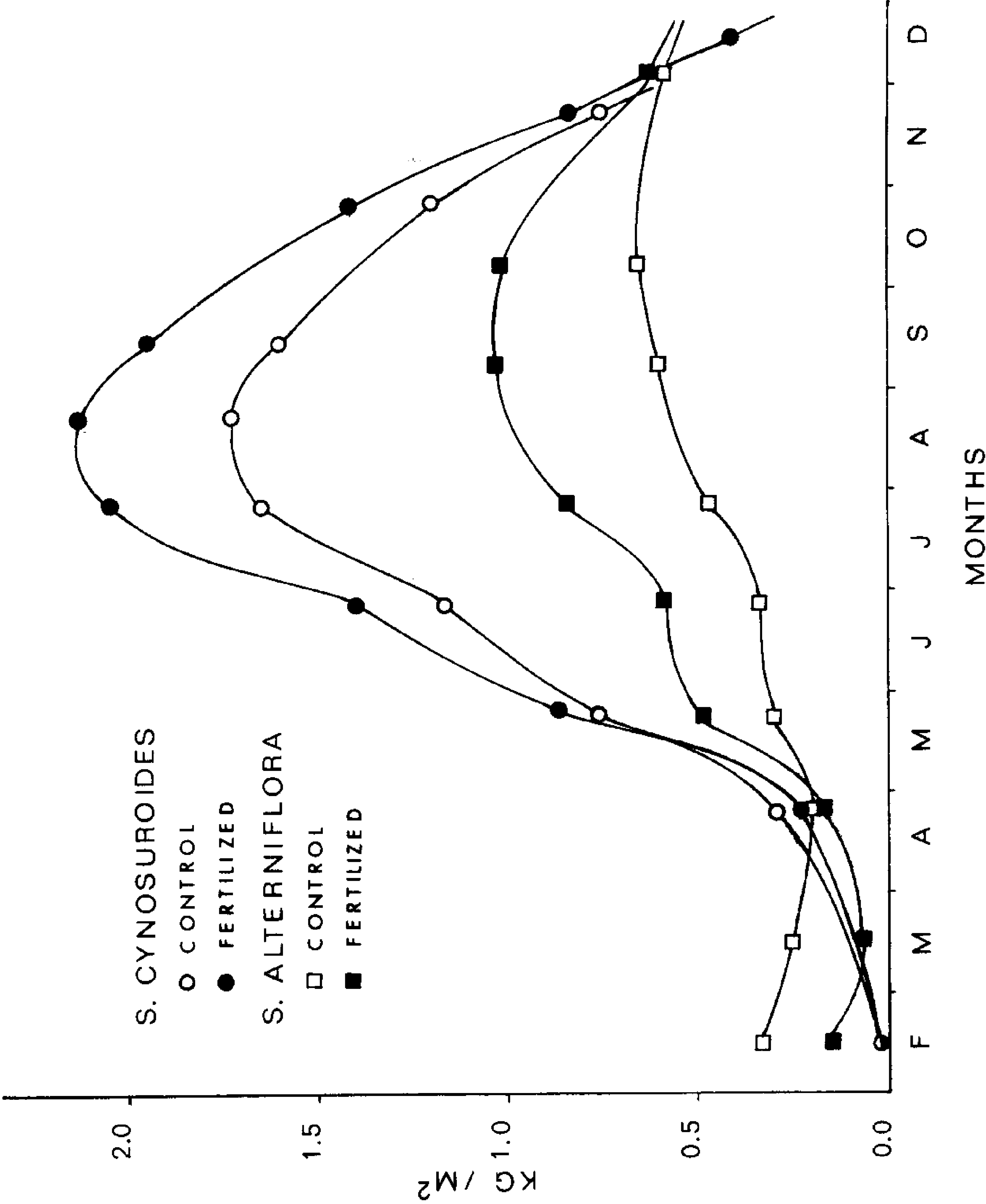

Figure 2. Periodic max-min curves for Spartina alterniflora and S. cynosuroides based on monthly standing crop of live plants.

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The Effects of Harvesting on the Productivity of Selected Gulf Coast Marsh Species

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The Effects of Harvesting on the Productivity of Selected Gulf Coast Marsh Species

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ABSTRACT

A simulated winter harvest was applied to three common Gulf Coast tidal salt marsh species (*Juncus roemerianus* and *Spartina alterniflora* in Alabama; *S. cynosuroides* and *J. roemerianus* in Mississippi). Aboveground living and dead plant material was manually clipped and removed ("harvested") from study plots in winter 1977, from the same plots (reharvest), and additional plots, in winter 1978. Annual net primary productivity was determined by applying a predictive periodic model, corrected for loss of dead material, to monthly 0.25 m^2 biomass samples. A single harvest resulted in an increase in annual net productivity of as much as 50% in the Mississippi *J. roemerianus* and 140% in *S. cynosuroides*. When the species were reharvested, net productivity increased up to 100% in Mississippi *J. roemerianus*, 45% in *S. cynosuroides* and 250% in *S. alterniflora*. Alabama *J. roemerianus* showed consistently lowered levels of productivity in harvested plots.

INTRODUCTION

No harvest of marsh plants of significant economic impact is employed in the U.S. Though once a common practice, particularly in east coast marshes, harvesting of "marsh hay" is now an infrequent occurrence. However, if any of the recent work on chemical derivatives (Miles and de la Cruz, 1976) and on the pulping potential (de la Cruz and Lightsey, Unpubl. ms.) of marsh plants proves to be of economic value, the prospect exists of regularly harvesting certain marsh plants for chemicals, cellulose, and other by-products and employing agriculture techniques to farm marsh grass in plantation fields.

Various marsh plants are grazed by cattle along the eastern and Gulf Coasts (Chabreck, 1978). This repeated harvest of biomass and the trampling effect of the cattle has been shown to diminish the yield of grazed plants (Williams, 1955; Reimold, et al, 1975). Reimold, et al (1975) found an increase in mean dry weight biomass following simulated grazing in a Georgia Spartina alterniflora marsh. Clipping experiments in a Mississippi mixed brackish marsh indicated that neither repeated clippings nor single clippings altered the growth rate of the plants (Gabriel and de la Cruz, 1974).

Increased human occupancy of coastal areas has historically and increasingly jeopardized the existence of tidal marsh resources. Dwindling marsh acreage results in a proportionately greater importance to the estuarine ecosystem of those marshlands remaining. Activities conducted within marshes must, therefore, be compatible with maintenance of the natural system function and not diminish the production role of the plants. In addition, the potential harvest of marshlands for products of direct value to mankind implies a cropping system that will produce maximum biomass yield.

The objective of our study was to determine the effect of a single harvest and repeated annual harvests on selected dominant Gulf Coast marsh species.

MATERIALS AND METHODS

100 m^2 experimental plots were established in each of four marsh communities: Juncus roemerianus and Spartina cynosuroides in Mississippi

and J. roemerianus and Spartina alterniflora in Alabama. The Mississippi study area was located on a marsh island on the western side of St. Louis Bay in Hancock County, Mississippi, an area previously described by de la Cruz (1973) and Gabriel and de la Cruz (1974). Two marshes on the leeward shore of Dauphin Island, Mobile County were utilized as the Alabama study sites. Species composition and environmental setting of two Dauphin Island study sites have been described by Stout (1978). The substrates of the two Alabama marshes are of higher salinity, greater sand content, and lower organic matter concentration than the Mississippi marsh. Both J. roemerianus communities were of short-medium plants (average 1.0 m in height), although the Mississippi J. roemerianus is more of a high marsh community than the one in Alabama. The S. cynosuroides was about 2-3 m in height while the S. alterniflora community was an inland high marsh with short plants (0.5 m).

One of the study plots was manually clipped, using grass shears, in mid-February, 1977. All clipped material and litter on the substrate was removed from the plot. In 1978, an additional plot was similarly harvested and the 1977 experimental plot was reclipped. A second and third plot each year, respectively, was used as a control. Six 0.25 m^2 samples were taken monthly from each study plot from April through December. Samples were sorted into living and dead plant material, dried at 100°C to constant weight, and weighed.

Annual net aboveground primary productivity (NAPP) was estimated from changes in standing live biomass using maximum-minimum values obtained by the predictive periodic model (PPM) of Hackney and Hackney (1978). The PPM technique was also applied to monthly dead biomass data from another plot, cleared of all biomass by burning, to obtain a correction value for loss of biomass due to death. This correction value was then added to the maximum-minimum value of live biomass for each marsh community.

RESULTS AND DISCUSSION

Table 1 summarizes the annual net primary productivity of both control and harvested plots. Clipping resulted in a significant increase in primary production of 26-106% in the Mississippi *Juncus roemerianus* community for both years of the study, 46-141% in *Spartina cynosuroides* during 1978 and in *S. alterniflora* an increase of 248% when reharvested only. The Alabama *J. roemerianus* community exhibited consistently lowered primary productivity in all clipped plots.

The net aboveground primary productivity of 460-658 gm-2 yr-1 for the control *J. roemerianus* plot is comparable to values reported for high marsh *J. roemerianus* (595 gm-2 yr-1) in North Florida (Kruczynski et al, 1978). The 571 gm-2 yr-1 NAPP for control *S. alterniflora* in 1978 is comparable to values (581 gm-2 yr-1) for a similar marsh in Barataria Bay, Louisiana (Kirby and Gosselink, 1976) although the 1977 value of 240 gm-2 yr-1 is significantly lower. Previous investigations by de la Cruz (1975) of similar marshes yielded comparable values of NAPP (2190 gm-2 yr-1) to the values of the control *S. cynosuroides* (1430-1740 gm-2 yr-1) in our study.

Table 2 summarizes the PPM statistics utilized to generate the max-min curves of Figures 1-4. After reviewing 1978 results, a two harmonic model was applied to the 1978 biomass data for Mississippi *J. roemerianus* to accomodate the two growth peaks seen in Figure 1.

Growth patterns of the two *J. roemerianus* communities differed as did

Table 1. Summary of annual net aboveground primary productivity (NAPP) of 1977 and 1978 control and clipped plots in four marsh communities. Tital NAPP was estimated from max.-min. values of periodic models presented in Table 2, corrected for loss of dead material.

Net Aboveground Primary Productivity (gm^{-2} yr^{-1}) MARSH COMMUNITY	CONTROL	CLIPPED
1977: Single clip application		
Juncus roemerianus (MS)	580	877
J. roemerianus (AL)	460	270
Spartina alterniflora	240	33
S. cynosuroides	1740	1755
1978: Single clip application		
Juncus roemerianus (MS)	540	681
J. roemerianus (AL)	658	414
Spartina alterniflora	571	305
S. cynosuroides	1430	3450
1978: Reclip of 1977 Experimental Plot		
Juncus roemerianus (MS)	540	1113
J. roemerianus (AL)	658	275
Spartina alterniflora	571	1987
S. cynosuroides	1430	2089

Table 2. Periodic models for four natural marsh communities and treated (clipped) study plots in each.

$$Y + C_0 + C_1 \sin (ct_i) + C_2 \cos (ct_i)$$

Juncus (MS) 1978 $y = C_0 + C_1 \sin (ct_i) + C_2 \cos (ct_1)$

$$+ C_3 \sin (ct_i) + C_4 \cos (ct_i)$$

COMMUNITY TREATMENT

1977	C_o	C_1	C_2	r^2
J. roemerianus control (MS)	687.0	-143.2	-182.6	0.3936
J. roemerianus clip (MS)	546.3	-217.8	-19.7	0.6056
J. roemerianus control (AL)	646.0	144.0	-177.4	0.2924
J. roemerianus clip (AL)	377.2	-85.0	105.6	0.3622
S. alterniflora control	227.7	16.3	-126.5	0.3521
S. alterniflora lcip	194.0	19.4	19.5	0.0246
S. cynosuroides control	606.4	-344.5	-675.5	0.6958
S. cynosuroides clip	804.1	-427.7	-691.4	0.7403

1978	C_o	C_1	C_2	C_3	C_4	r^2
J. roemerianus control (MS)	858.3	-209.0	-54.7	-106.6	33.8	0.3730
J. roemerianus clip (MS)	567.9	-221.0	49.0	71.7	-2.63	0.5200
J. roemerianus reclip (MS)	635.5	-265.6	137.2	-11.9	147.0	0.7200
J. roemerianus control (AL)	129.8	-17.6	26.4	-	-	0.2078
J. roemerianus clip (AL)	66.4	-41.4	-5.9	-	-	0.7208
J. roemerianus reclip(AL)	52.8	-32.1	10.6	-	-	0.6032
S. alterniflora control	107.2	-52.6	19.7	-	-	0.7200
S. alterniflora clip	103.1	-75.6	9.0	-	-	0.7130
S. alterniflora reclip	94.7	-82.6	29.9	-	-	0.8340
S. cynosuroides control	847.1	-764.6	-441.5	-	-	0.7500
S. cynosuroides clip	1040.4	-694.5	-801.8	-	-	0.6300
S. cynosuroides reclip	843.7	-508.6	-374.0	-	-	0.4000

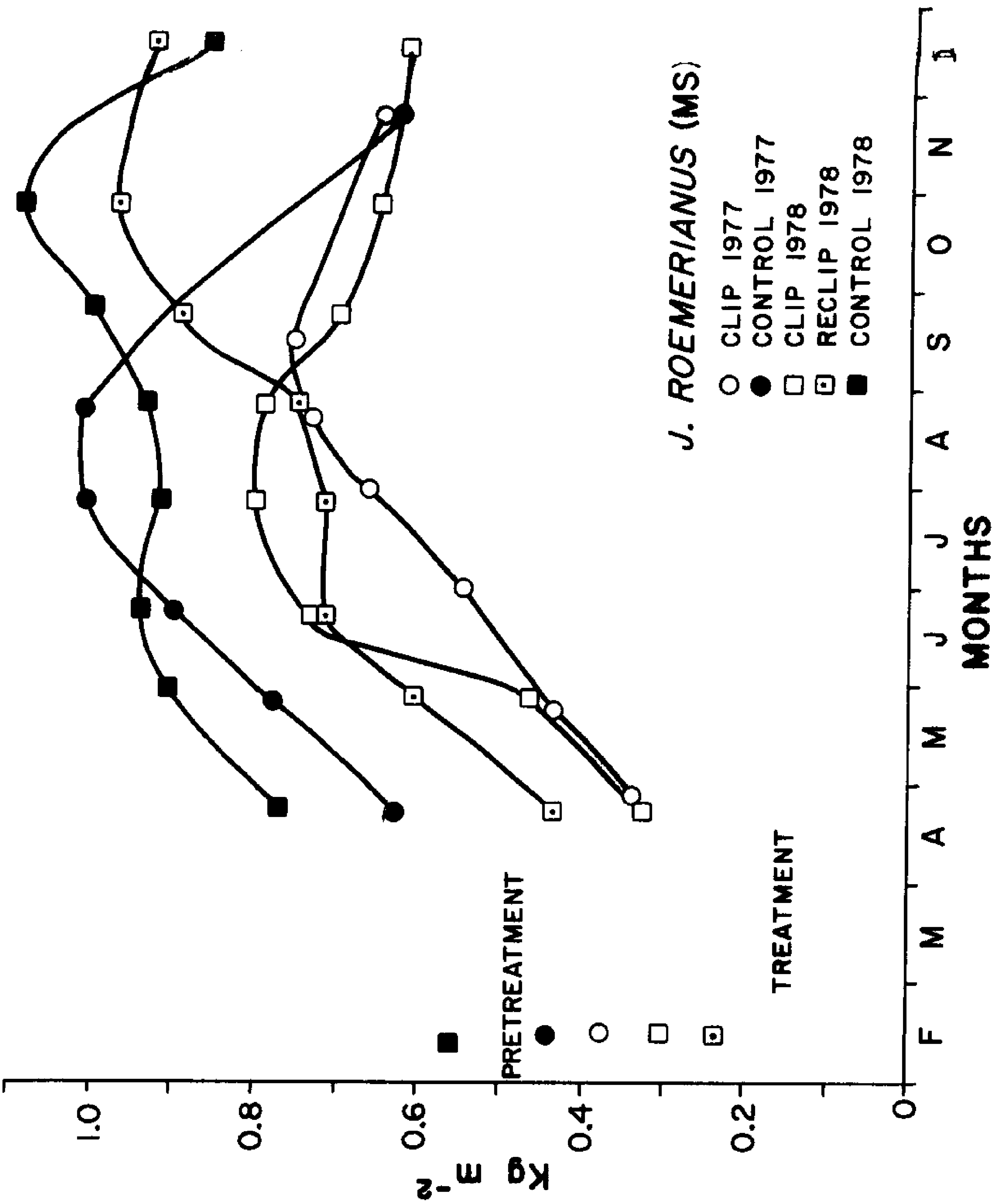

Figure 1. Periodic max.-min. curves for Mississippi Juncus roemerianus based on monthly standing crop of live plants.

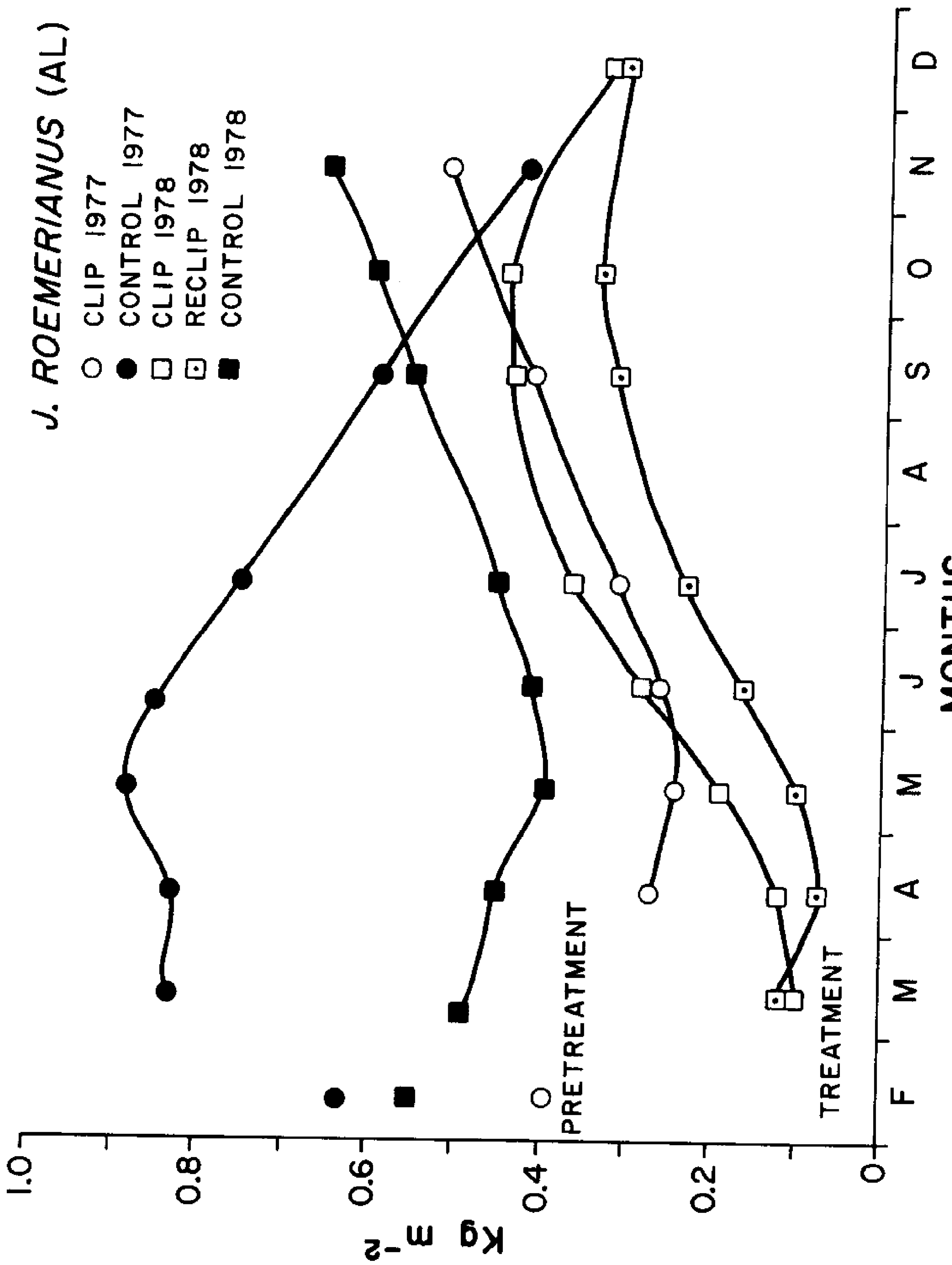

Figure 2. Periodic max.-min. curves for Alabama Juncus roemerianus based on monthly standing crop of live plants.

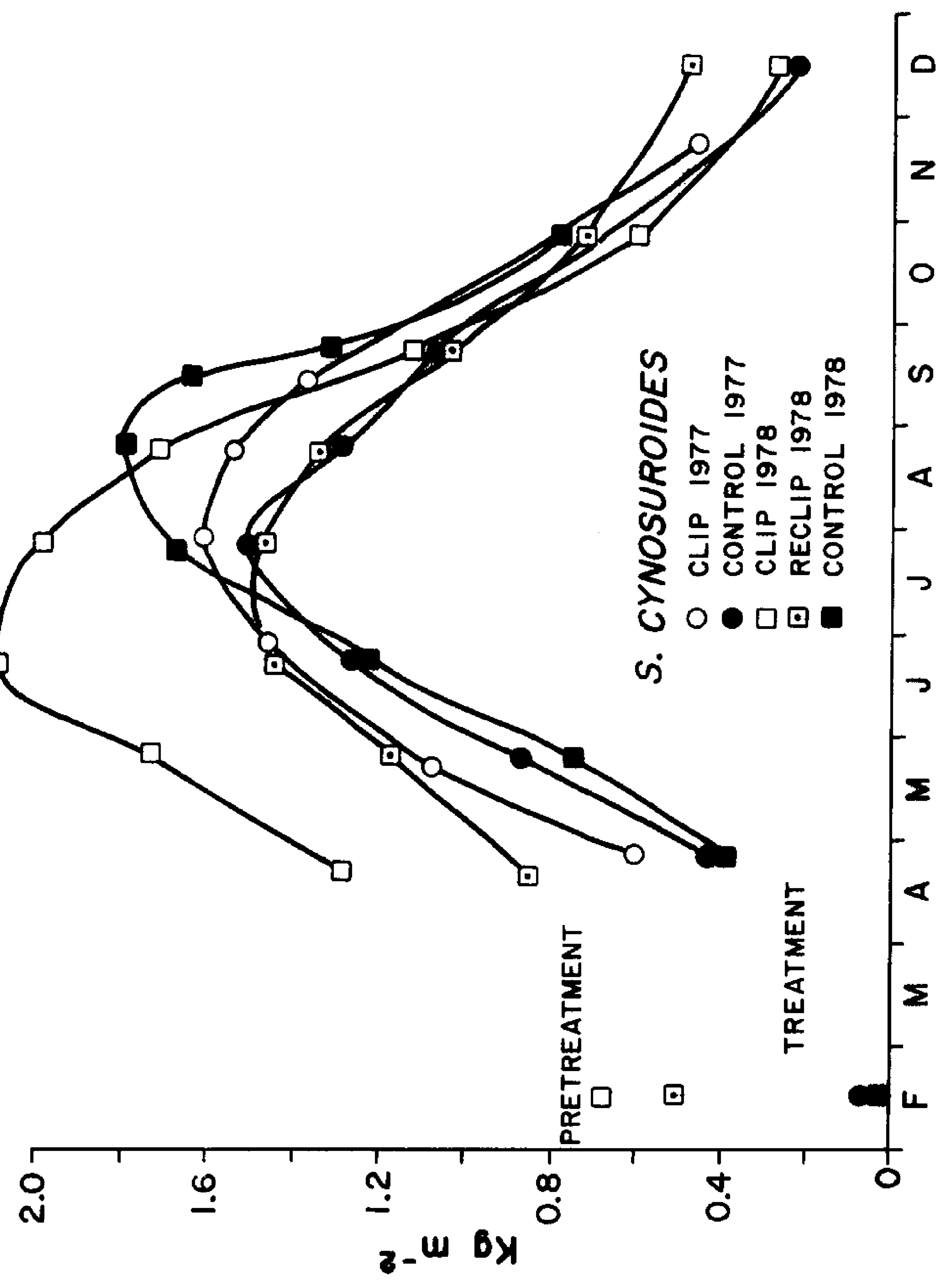

Figure 3. Periodic max.-min. curves for Spartina cynosuroides based on monthly standing crop of live plants.

the response of each to the clip treatment. The Mississippi community yielded peaks in live biomass in June and again in October. The Alabama Juncus marsh did not show a biomodal pattern, reaching a single peak in biomass in early fall (Figure 2). NAPP of both communities was not significantly different between the control plots. However, when clipped the Alabama marsh responded by a lowering in NAPP while the Mississippi marsh showed increased productivity, as great as four times that found in Alabama for the same treatment. Extensive peat deposits beneath the Mississippi marsh, absent in Alabama, may indicate a greater age for the marsh. Removal of accumulated standing material, both living and dead, from the older marsh may have provided greater space and sunlight for new leaf production, relative to pretreatment conditions, than in the younger, less dense Alabama marsh. Within the study period, live standing biomass reached control levels only in the Alabama 1977 clip plot and the Mississippi 1978 reclipped plot.

Spartina cynosuroides exhibits a very distinct annual growth pattern, with winter death of aboveground culms. February harvest removed mostly dead material. Growth patterns in all plots were similar (Figure 3). Standing live biomass peaked in mid-to late summer with levels in treatment plots exceeding control plots from the onset of annual regrowth. Reduction of shading and crowding by the previous years dead culms may have been a significant factor in the increased productivity with clipping.

The Spartina alterniflora community was the most regularly flooded of the four areas studied. Water frequently covered the marsh to depths of several inches, even at low tide. Trampling and compaction of the substrate due to harvesting activities was very severe in this marsh. Many plants showed no regrowth and rotted areas were common within the plots as the study progressed (Figure 4). Lowered productivity in both single clip plots was the result of fewer plants due to plant death and not lowered individual plant biomass production. Reharvest of the 1977 plot in February, 1978 was easily and rapidly accomplished without significant damage because of the lowered plant density. Recovery and vegetative expansion in this plot resulted in the largest percentage increase (250%) over control of any community. If harvesting is determined to be of economic value, techniques with a low disruption factor must be found for marshes such as the *S. alterniflora* marsh with soft, saturated, easily disturbed substrates.

Effects of harvesting plant materials vary between species of marsh plants. There appears to be little detrimental effects on productivity and there may even be an increase in biomass production as a result of harvesting. The effects of different harvesting methods and of repeated annual harvest beyond the second year need to be examined before the impact upon the plant communities can be adequately evaluated. In addition, the impact upon other biotic components and system interaction must be determined.

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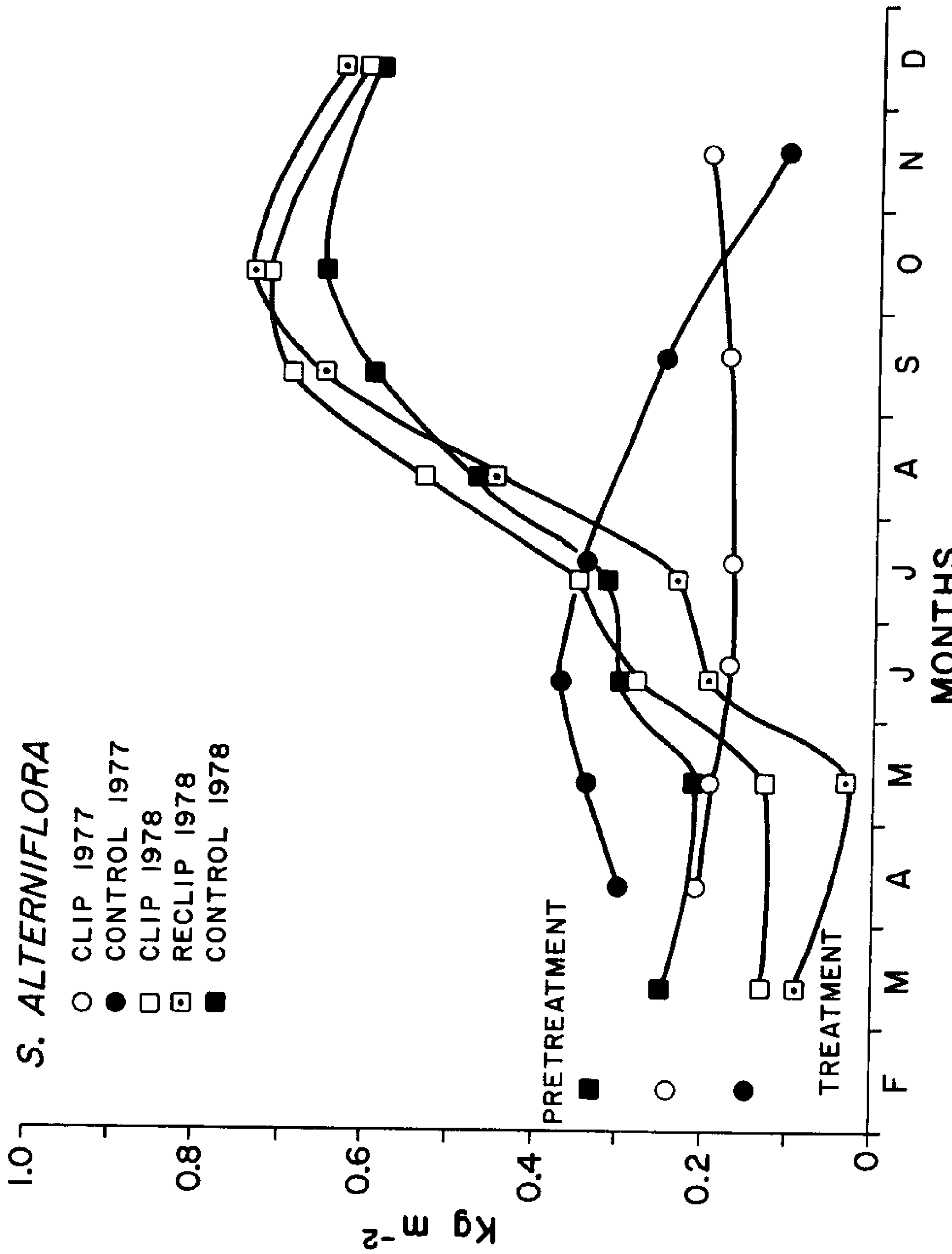

Figure 4. Periodic max.-min. curves for *Spartina alterniflora* based on monthly standing crop of live plants.

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The Effects of Winter Fire on the Vegetational Structure and Primary Productivity of Tidal Marshes in the Mississippi Gulf Coast[1]

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[1]This portion of the project is continuing for a third year. This study on the effects of burning on the marsh, when completed, will cover a period of four years since a preliminary study was conducted in 1976 under a grant from the Mississippi Marine Resources Council (Project No. GR 76-003). A separate monograph on this subject will be prepared and published by de la Cruz and Hackney at the conclusion of the 1979 continuation study.

ABSTRACT

The effects of fire on two tidal marshes in Mississippi was studied for two growing seasons following a fire. Burning the marsh during winter enhanced the productivity of the vascular plant community dominated by Spartina cynosuroides during the following growing season. Productivity and the biomass of dead and live material returned to normal levels at the end of the second growing season. On the marsh dominated by Juncus roemerianus, productivity was also higher during the next growing season following a fire. Associated minor species did not increase significantly their importance relative to the dominant plant species after burning in either marsh community.

INTRODUCTION

Fire as a method for improving habitat for wildlife has been used haphazardly by trappers and hunters along the Gulf Coast for many years (Chabreck 1976). For commercial trappers, improved marsh habitat means higher population of muskrat (Ondatra zibethica) and nutria (Myocastor coypus) which are economically important pelt mammals. Myers (1956) and Whipple and White (1977) both reported an increase in Scirpus species following a fire. Scirpus species are the favorite food of marsh mammals as evidenced by preferential grazing observed by the authors and by the accounts of local trappers. Marsh burning has been also suggested as a method of improving habitat for game birds such as migrating ducks and geese (Chabreck 1976) and may also maintain the proper nesting habitat for mottled ducks, Anas fulvigula maculosa (Hackney and Hackney 1976).

Besides the obvious loss of large amounts of organic material and some changes in plant species composition, little is known about the effects of fire on tidal marshes. Most previous studies have been aimed at the improvement of wildlife habitat and so were interested in converting plant communities containing species (e.g., Juncus roemerianus, Distichlis spicata and Spartina patens) which are not considered favorable to wildlife, to communities which provide better quality food (Myers 1956 1956; Hoffpauir 1961; McNease and Glasgow 1970; Whipple and White 1977). Indeed Scirpus species contain higher protein concentrations than other marsh species (de la Cruz 1973; de la Cruz and Poe 1975). Myers (1956) reported an increase in the diversity of a multi-species marsh dominated by Juncus roemerianus following a burn, but little species change occurs in monospecific communities. In some areas, fires are so prevalent that, it is impossible to determine the original species composition (Whipple and White 1977) of the community. Other factors that may change species composition of marshes are changes in water levels and salinity regimes.

The marshes surrounding St. Louis Bay, Mississippi, have not been biotically altered by changes in water levels or salinity regimes, and the St. Louis Bay estuary is one of the most pristine along the Gulf Coast. The vascular flora of these marshes is very diverse (Gabriel and de la Cruz 1974). Two major community types can be distinguished: 1) marshes dominated by the black needlerush *Juncus roemerianus* and 2) marshes dominated by the giant cordgrass *Spartina cynosuroides*.

The purpose of this study was to determine the effects of winter fire on the species composition and productivity of a *Juncus roemerianus* and a *Spartina cynosuroides* marsh.

MATERIALS AND METHODS

This study was conducted on a marsh island on the western side of St. Louis Bay in Hancock County, Mississippi. The plant communities on this island were previously described by de la Cruz (1973) and Gabriel and de la Cruz (1974). Winter fires have occurred regularly on this island at intervals of two to three years, but the two study sites, as far as known, have not been burned since 1973. The *Juncus roemerianus* marsh was located on the southwestern side of the island approximately 100 meters south of a small tidal creek. The *Spartina cynosuroides* community was located on the eastern side of the island about 20 meters from a larger tidal creek. The two marshes appear monotypic, but each harbors at least three minor associated species.

Paired plots (10 x 10 m) were established in the two marsh communities during mid-February 1977. One plot was burned to the ground and the other served as control.

Six 0.5 x 0.5 m plots were collected monthly from April through September 1977 from each plot in the *J. roemerianus* and *S. cynosuroides* communities. All living and dead materials were removed from each harvested plot including litter. Using the same procedures, a sample was collected in February before the burn and in November after most of the seasonal growth had occurred. An additional collection was made on December 20, 1977. Using the wooden stakes as reference points, a random stratified sampling procedure was used. Such a procedure randomly collected from within this subarea. Primary productivity was estimated from the monthly increases in biomass during the growing season using a predictive periodic model described by Hackney and Hackney (1978).

Each sample was transported to the laboratory where it was separated into living and standing dead plants (those plants that were dead, but still attached to the roots or rhizomes), and litter on the ground. Living plants were separated according to species, dried at 103° C and weighed. A sample of the dominant living vegetation from each area was retained for caloric and ash-free weight determinations.

Six belowground samples were collected from each experimental and control plot at the same time as the aboveground with a coring device (10 cm diameter) previously described by de la Cruz and Hackney (1977).

Each core section was transported to the laboratory and washed thoroughly, bur carefully, in running tap water over a 1 mm sieve. Living and dead rhizome/root materials were not separated. Each core was dried to a constant weight at 103° C. A subsample from the A and B core-section was retained from each collection period for caloric and ash-free weight analyses.

Additional aboveground and belowground samples were collected from each area and dried at 50° C for analyses of carbon, hydrogen, nitrogen and phosphorous content. All samples for elemental, caloric and ash-free weight analyses were ground in a Wiley Mill with a No. 60 sieve. All samples were analyzed as follows: ash-free dry weight by combustion at 550° C for six hours; energy content by combustion in a Paar Adiabitic Bomb Calorimeter Model 1214; carbon and hydrogen by means of a Coleman C-H Analyzer Model 33; and nitrogen by means of a Coleman N Analyzer Model 29-021. Total phosphorous was determined according to the method outlined by Howitz (1975).

In mid-February 1978, new experimental plots were established. A winter fire was simulated in early March on the new plots. The 1977 experimental plots were also reburned to determine the effects of a two-year consecutive burning.

RESULTS AND DISCUSSION

The annual aboveground net primary productivity of *Juncus* and *Spartina* marshes which received one simulated winter fire and two consecutive winter fires are summarized in Table 1. It is evident from both control and experimental data that the marshes were more productive during the 1978 growing season than in 1977. As has been already indicated elsewhere (Stout, Hackney and de la Cruz, p. this report), the lower productivity value in 1977 was due to the severe and prolonged winter conditions which presumably suppressed the winter growth of J. roemerianus and which killed S. cynosuroides early in November 1977 (See Appendix, Tables 15 and 17). In general, the Spartina marsh was three to four times more productive than the Juncus marsh and they showed quite different growth patterns (Figures 1 and 2). Since the Spartina marsh is totally killed to the ground in winter, higher productivity was reflected in both the 1978 control (39%) and experimental (45%) marshes. This rate of increase did not occur in the Juncus marsh; the 1978 control marsh was only 22% higher than 1977 and the burn plots did not show any increment. Juncus, unlike Spartina, does not get killed in winter so that winter growth in the Juncus control marsh may have been partially responsible for the 22% increase.

Juncus Marsh. There was 11% (1978) to 33% (1977) increase in productivity of the plots that were burned in the winter preceeding the growing season. When the 1977 experimental marsh was reburned the following year, biomass production was 40% more than the control indicating that the two successive winter fires have not affected plant productivity. The two experimental plots showed similar patterns of growth following winter fire (Figure 1) with peak standing crop in late summer (August-September). When burned a second time the following winter, the 1977 plot showed a growth pattern with two harmonic curves or standing crop peaks in June and October.

Table 1. Summary of aboveground net primary productivity ($g/m^2/yr$) of natural and experimental marshes which received one simulated winter fire (1978) and two consecutive winter fires (1977).

MARSH	CONTROL	ONE FIRE	TWO FIRES
J. roemerianus			
1977	584	875	-
1978	753	847	1265*
S. cynosuroides			
1977	1737	2152	-
1978	2860	3925	3765*

*Burned during 1977 and 1978 winters.

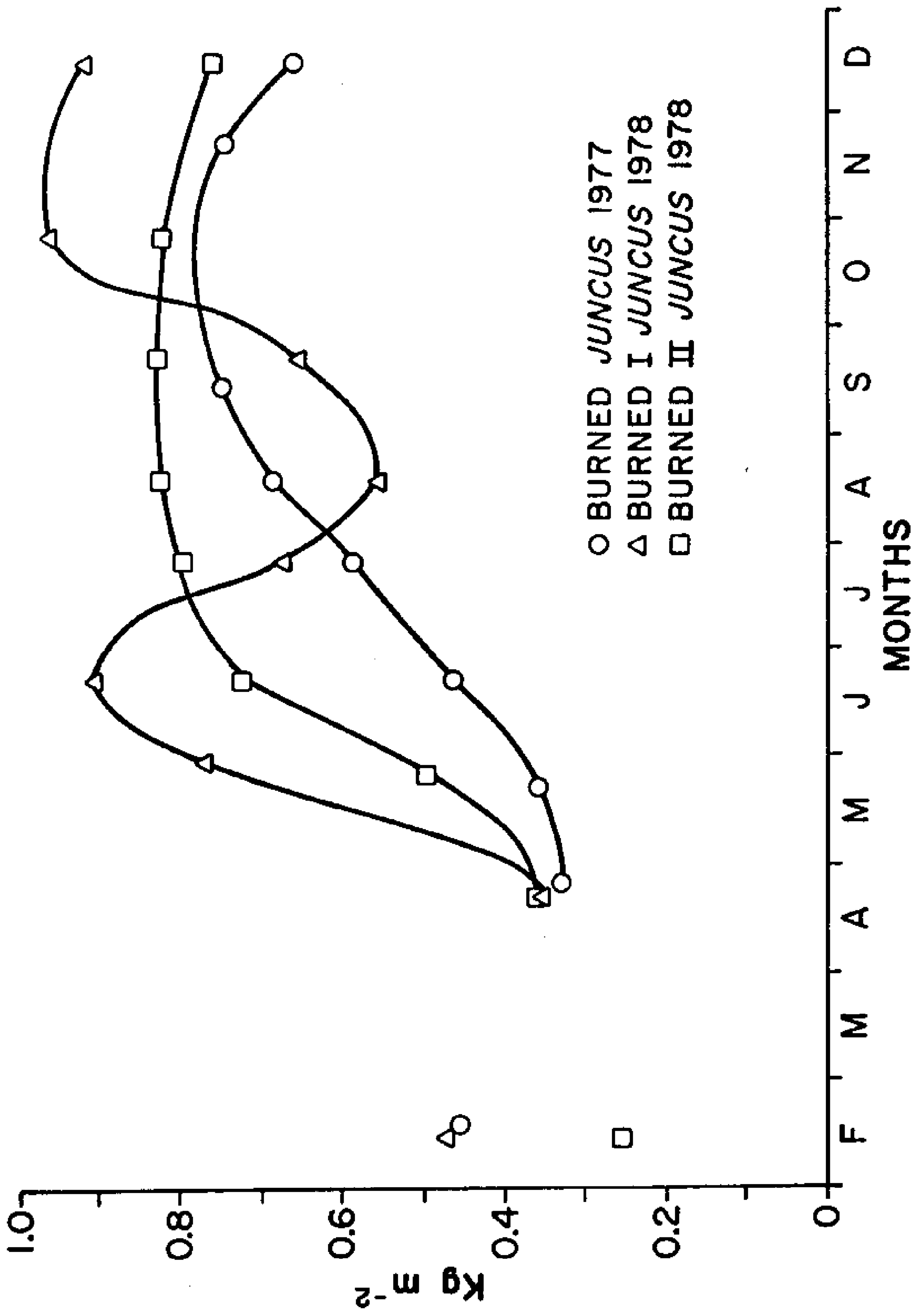

Figure 1. Periodic max.-min. curves for J. roemerianus.

Spartina Marsh. There was 19% (1977) to 27% (1978) increase in productivity of the plots that received simulated fire during the winter preceeding the growing season. A second fire during the following winter in the 1977 experimental plot also resulted in about 24% increment in biomass production indicating that the Spartina marsh was also not affected by two consecutive annual winter fires. The two experimental plots showed the same pattern of monthly biomass increase in 1977 and 1978 (Figure 2). Peak biomass occurred in July and dropped down to low levels (similar to the first month's growth in April) in November (for 1977) and December (for 1978). This bell-shaped biomass curve is characteristic of Spartina spp. and other plants whose tissues are totally killed by winter frosts.

The aboveground net productivity values obtained in this study for the control or natural Juncus marsh of 584-753 $g/m^2/yr$ is comparable to the 595-949 $g/m^2/yr$ range reported by other workers (de la Cruz 1974; Fanning and Odum 1970). It is apparent that both marsh communities increased in productivity in response to winter fire. The increase in Spartina is higher than in Juncus and that growth and biomass yield is influenced by seasonal and annual variation in climate.

Standing crop of belowground materials was the same throughout the year in both marshes; thus, no productivity estimate could be made (See Appendix, Tables 23 and 26). The caloric value and nutrient (C, H, N, P) concentrations in the monthly samples of above- and below-ground materials were not statistically different between the control and experimental plots. This aspect of the study is presented in the Appendix, Tables 29, 31, 37 and 39.

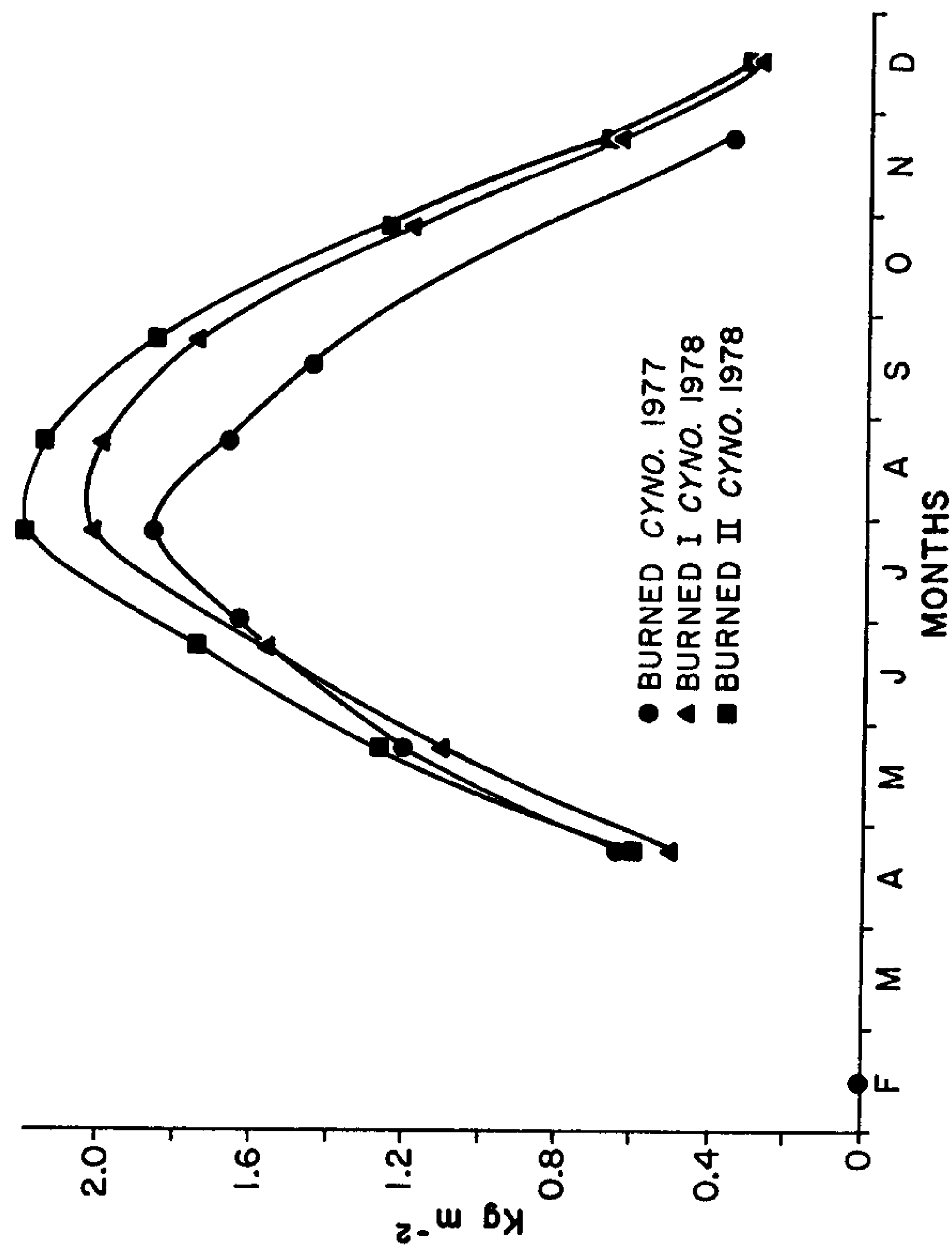

Figure 2. Periodic max.-min. curves for S. cynosuroides.

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APPENDIX

I. Tables 1-22: Monthly standing crop of aboveground materials in the control, burned, clipped and fertilized plots of all marsh communities.

II. Tables 23-28. Monthly standing crop of belowground materials at 0-10 cm and 11-20 cm depth levels in the control, burned, clipped and fertilized plots of all marsh communities.

*III. Tables 29-44: Caloric values and nutrient (C, H, N, and P) concentrations of aboveground and belowground tissues of all marsh species studied from all treatment plots.

IV. Table 47: Summary statistics of caloric and nutrient analyses.

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*These data will be incorporated in a compendium on "Energy and Nutrient Values of Marsh Biota" under preparation by Dr. A. A. de la Cruz.

Table 1. Average biomass ($\bar{x}$) and standard deviation (s) of live and standing dead plant shoots, total litter, number of minor species, and total live biomass (g/m^2) of all species in the control *J. roemerianus* community in Mississippi.

Date	Live $\bar{x}$	Live s	Dead $\bar{x}$	Dead s	Litter $\bar{x}$	Litter s	Assoc. Minor Spp. $\bar{x}$ no.	Total Live Biomass of All Species $\bar{x}$	Total Live Biomass of All Species s
2-14-77	581.3	139.3	860.7	242.4	284.7	60.6	1.0	604.3	150.9
4-27-77	379.2	138.8	598.0	146.4	230.1	56.8	1.8	468.3	163.6
5-25-77	448.0	89.8	557.3	138.2	502.7	126.3	2.0	665.0	184.0
6-29-77	805.2	112.4	801.3	122.7	381.5	123.7	3.0	982.0	111.8
7-29-77	872.0	187.2	798.0	130.5	204.1	66.9	2.7	1060.0	235.7
8-26-77	740.0	146.8	1051.3	149.3	290.1	117.3	2.7	948.3	157.4
9-17-77	538.8	66.0	984.0	90.9	242.1	70.1	1.8	684.6	119.3
11-26-77	481.3	166.9	799.6	346.2	261.4	39.9	2.0	601.4	137.1
2-18-78	546.7	22.22	641.3	29.26	390.0	19.42	1.2	599.0	95.08
4-23-78	526.7	27.25	859.3	45.32	220.8	7.36	3.0	654.67	113.58
5-27-78	607.4	59.62	615.3	22.74	252.0	11.40	3.9	959.33	97.31
6-24-78	649.3	16.35	611.3	12.27	365.3	11.29	3.2	989.33	279.01
7-28-78	474.0	5.4	1203.3	44.8	324.0	14.1	3.0	812.0	85.19
8-26-78	610.0	41.5	806.0	23.6	449.3	18.3	2.3	994.7	225.94
9-22-78	586.6	16.7	567.3	30.5	736.6	38.2	2.7	1155.33	258.73
10-28-78	598.7	27.0	952.7	60.8	466.0	27.9	2.3	980.7	181.33
11-26-78[1]	-	-	-	-	-	-	-	-	-
12-16-78	637.3	54.5	910.7	28.9	734.7	35.5	2.3	885.33	295.59

[1]Samples were lost due to fire in the drying oven.

Table 2. Average biomass ($\bar{x}$) and standard deviation (s) of live and standing dead plant shoots, total litter, number of minor species and total live biomass (g/m^2) of all species in two fertilized[1] _J. roemerianus_ communities in Mississippi.

Date	Live		Dead		Litter		Assoc. Minor Spp.	Total Live Biomass of All Species	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$ no.	$\bar{x}$	s
2-14-77[2]	515.0	104.5	873.0	179.6	290.7	34.7	1.2	540.7	101.6
4-27-77	476.3	64.7	704.6	229.4	237.4	45.8	2.7	716.7	88.2
5-25-77	693.6	142.0	463.3	140.4	492.1	97.2	2.8	888.7	170.0
6-29-77	630.6	325.6	571.3	137.4	271.4	60.9	2.8	924.0	376.2
7-29-77	558.0	124.3	662.0	263.7	162.8	34.4	2.8	897.3	190.8
8-26-77	732.6	140.8	562.2	92.0	372.1	84.7	3.3	1037.0	198.9
9-17-77	411.3	197.2	512.6	196.0	325.4	60.8	2.8	916.7	177.2
11-26-77	550.6	144.9	942.6	328.7	307.4	50.6	1.0	782.1	158.8
2-18-78[2]	505.6	16.64	613.6	28.74	279.6	10.51	1.4	539.3	67.19
4-23-78	458.8	30.27	637.6	21.37	202.0	7.71	2.7	661.3	138.51
5-27-78	851.6	43.89	785.6	64.53	286.8	11.02	3.0	1168.0	114.88
6-24-78	890.0	25.45	457.3	39.49	212.0	14.18	3.0	1314.7	140.03
7-28-78	681.0	18.0	714.0	27.9	274.0	15.8	2.7	932.7	70.85
8-26-78	771.3	47.7	913.3	38.2	418.7	30.4	2.3	1269.33	236.96
9-22-78	674.0	58.7	644.0	37.2	546.6	32.0	2.5	1464.67	236.13
10-28-78	714.7	38.6	969.3	29.3	465.3	42.4	3.8	1362.67	398.81
11-26-78	-	-	-	-	-	-	-	-	-
12-16-78	704.7	37.1	825.3	30.5	632.0	39.3	2.3	1493.3	380.86

[1]Fertilized with 7.1 kg 13-13-13 per 10 m^2 on February 14, 1977 and 13.6 kg NH_4NO_3 (33% N) per 10 m^2 on February 18, 1978.

[2]Pretreatment sample.

[3]Samples were lost due to fire in the drying oven.

Table 3. Average biomass ($\bar{x}$) and standard deviation (S) of live and standing dead plant shoots, total litter, number of minor species, and total live biomass (g/m^2) of all species in the clipped[1] *J. roemerianus* community in Mississippi.

Date	Live		Dead		Litter		Assoc. Minor Spp.	Total Live Biomass of All Species	
	$\bar{x}$	S	$\bar{x}$	S	$\bar{x}$	S	$\bar{x}$ no.	$\bar{x}$	S
2-14-77[2]	424.7	129.6	844.3	216.2	407.4	131.7	1.0	463.3	127.7
4-19-77	167.7	26.3	0	0	327.4	85.4	1.7	263.7	42.0
5-25-77	250.0	54.4	0	0	202.8	97.3	2.2	384.0	108.6
6-27-77	373.3	47.2	2.7	3.0	92.1	36.2	2.7	660.0	166.3
7-29-77	422.7	59.4	56.7	15.3	175.4	91.1	2.7	656.0	143.1
8-26-77	499.3	82.1	32.0	6.7	109.8	61.2	2.5	728.7	91.0
9-17-77	417.3	138.8	89.3	37.2	191.5	72.4	3.0	752.7	130.0
11-26-77	497.3	76.6	185.3	32.1	173.4	81.4	2.5	616.1	95.6
2-1-78[2]	368.8	29.28	263.7	16.07	50.0	4.67	1.7	448.0	137.08
4-23-78	121.6	6.12	5.3	3.26	124.0	6.06	1.0	196.0	24.66
5-27-78	301.6	4.80	6.7	1.36	61.3	6.25	2.7	492.0	76.69
6-24-78	296.0	11.22	0	0	106.7	11.46	2.5	584.0	96.66
7-28-78	319.3	29.5	136.7	13.4	91.3	5.8	2.5	714.7	104.27
8-26-78	340.0	17.3	118.7	19.3	140.0	20.9	2.8	670.0	121.50
9-22-78	386.6	17.2	230.6	27.1	246.6	12.5	2.5	812.67	148.52
10-28-78	439.3	15.5	624.0	41.8	296.7	21.1	2.3	934.0	217.91
11-26-78	432.7	33.7	293.3	26.1	150.7	12.8	2.3	844.0	127.05
12-16-78	383.3	17.9	252.0	21.0	86.0	6.2	3.3	1025.33	217.24

[1]Cut February 14, 1977 and recut February 18, 1978.

[2]Precut sample.

Table 4. Average biomass ($\bar{x}$) and standard deviation (S) of live and standing dead plant shoots, total litter, number of minor species, and total live biomass (g/m^2) of all species in the Clipped II[1] *J. roemerianus* community in Mississippi.

Date	Live		Dead		Litter		Assoc. Minor Spp.	Total Live Biomass of All Species	
	$\bar{x}$	S	$\bar{x}$	S	$\bar{x}$	S	$\bar{x}$ no.	$\bar{x}$	S
2-1-78[2]	516.0	36.35	817.3	32.15	386.0	15.83	1.5	611.67	197.62
4-23-78	128.0	5.29	0[3]	0	250.0	25.76	1.7	204.7	44.07
5-27-78	172.0	3.49	0	0	86.0	14.36	3.7	455.3	74.29
6-24-78	260.0	14.28	0	0	28.7	2.56	2.8	466.67	107.05
7-28-78	272	20.5	92.0	8.7	76.7	6.4	4.0	592.67	117.86
8-26-78	495	57.4	176.0	13.7	86.7	4.6	3.0	816.67	180.99
9-22-78	544	31.1	215.3	26.1	429.3	22.8	3.0	997.33	200.35
10-28-78	314.7	16.7	315.7	18.9	62.0	8.6	3.8	492.7	57.99
11-26-78	393.3	10.7	282.0	4.1	63.7	4.3	3.0	674.67	94.98
12-16-78	396.3	14.2	257.3	14.8	97.3	9.6	2.2	685.33	183.04

[1] Cut February 18, 1978

[2] Precut samples

[3] Means no dead plants collected

Table 5. Average biomass ($\bar{x}$) and standard deviation (S) of live and standing dead plant shoots, total litter, number of minor species, and total live biomass (g/m^2) of all species in the Burn I[1] *J. roemerianus* community in Mississippi.

Date	Live		Dead		Litter		Assoc. Minor Spp.	Total Live Biomass of All Species	
	$\bar{x}$	S	$\bar{x}$	S	$\bar{x}$	S	$\bar{x}$ no.	$\bar{x}$	S
2-14-77[2]	520.0	111.1	1080.3	116.5	364.4	83.5	1.0	551.0	115.9
4-19-77	122.0	17.3	0	0	512.1	155.9	1.5	186.3	53.3
5-25-77	258.0	35.5	0	0	299.4	77.4	1.8	393.6	112.1
6-29-77	344.7	86.4	39.3	28.6	408.4	115.4	2.7	543.3	146.0
7-29-77	381.3	78.0	83.3	16.3	306.8	94.0	2.3	616.0	132.9
8-26-77	358.0	54.3	37.3	14.0	162.1	33.5	2.3	703.3	226.9
9-17-77	510.6	106.8	38.6	19.9	419.4	59.9	2.0	694.0	153.2
11-26-77	614.0	68.8	288.0	72.4	212.1	61.0	2.3	699.1	88.5
12-20-77	602.7	128.4	262.7	95.4			1.7	714.7	139.4
2-1-78[2]	322.4	46.04	319.6	24.66	251.6	11.99	1.7	361.7	185.11
4-23-78	315.6	25.61	544.0	31.58	215.6	9.19	1.5	412.00	122.27
5-27-78	449.6	21.25	244.0	13.16	88.0	6.32	3.2	799.67	156.94
6-24-78	662.7	41.83	337.3	32.44	112.7	11.44	2.8	900.0	194.68
7-28-78	288.0	20.6	318.7	37.7	143.3	14.9	3.0	655.33	55.04
8-26-78	371.3	32.0	268.0	36.5	128.7	10.4	2.3	577.33	70.96
9-22-78	451.3	56.1	695.3	41.3	377.3	21.7	2.3	773.80	191.37
10-28-78	287.3	24.2	420.7	31.5	152.7	15.5	2.5	816.67	125.46
11-26-78[3]	-	-	-	-	-	-	-	-	-
12-16-78	540.7	23.6	684.0	13.0	161.3	10.00	2.3	1102.7	262.84

[1]Burned February 14, 1977 and reburned February 18, 1978.

[2]Preburn sample.

[3]Samples were lost due to fire in the drying oven.

Table 6. Average biomass ($\bar{x}$) and standard deviation (S) of live and standing dead plant shoots, total litter, number of minor species, and total live biomass (g/m^2) of all species in the Burn II[1] *J. roemerianus* community in Mississippi.

Date	Live		Dead		Litter		Assoc. Minor Spp.	Total Live Biomass of All Species	
	$\bar{x}$	S	$\bar{x}$	S	$\bar{x}$	S	$\bar{x}$ no.	$\bar{x}$	S
2-1-78[2]	582.8	13.07	794.4	61.57	371.6	8.37	1.0	879.67	599.14
4-23-78	132.8	4.02	40.8	7.16	360.0	10.20	1.9	211.3	37.64
5-27-78	234.8	15.64	18.8	3.32	208.0	15.90	3.2	405.33	78.57
6-24-78	304.7	12.53	-	-	263.3	18.18	3.3	514.00	109.74
7-28-78	464.0	14.9	66.7	2.6	174.7	11.5	3.3	718.00	88.28
8-26-78	478.7	34.4	203.3	35.2	383.3	36.4	2.1	680.0	126.29
9-22-78	734.0	41.8	147.3	16.4	556.6	31.7	3.2	1037.3	275.83
10-28-78	497.3	27.8	236.0	23.2	206.7	11.5	3.0	754.0	135.97
11-26-78	457.0	38.1	497.0	14.6	344.0	23.7	3.5	735.3	193.88
12-16-78	617.3	59.6	357.7	39.0	386.7	16.1	2.3	866.00	169.47

[1] Burned February 18, 1978

[2] Preburn sample

Table 7. Average biomass ($\overline{x}$) and standard deviation (s) of live and standing dead plant shoots and total plant biomass (g/m^2) in the control *J. roemerianus* community in Alabama.

Date	Live $\overline{x}$	Live s	Dead $\overline{x}$	Dead s	Total Biomass $\overline{x}$	Total Biomass s
2-17-77	695.8	158.2	2009.1	312.0	2704.9	451.5
4-20-77	742.0	123.0	1512.0	214.0	2254.6	281.8
5-19-77	857.0	249.5	1610.9	143.5	2467.9	246.4
6-22-77	803.6	187.0	1609.9	258.2	243.5	418.7
7-26-77	1009.2	378.5	1270.4	195.3	2279.6	531.4
8[1]	-	-	-	-	-	-
9-07-77	379.7	83.8	898.6	310.4	1278.3	390.5
11-28-77	544.5	69.8	1879.1	219.4	2423.6	175.7
2-15-78	422.57	76.88	1235.03	333.1	1657.6	378.19
3-15-78	501.66	90.96	1183.7	304.22	1685.29	363.83
4-19-78	558.9	186.77	1649.08	244.45	2208.78	373.66
5-24-78	230.95	51.22	573.4	332.75	804.35	318.20
6-28-78	365.75	52.46	582.46	152.04	948.21	125.50
7-27-78	506.82	68.01	624.27	168.19	1131.09	134.44
9-01-78	549	127.69	573.14	76.59	1122.14	146.92
10-06-78	429.76	94.04	971.08	157.6	1400.84	204.12
12-05-78	773.05	120.49	759.04	288.81	1532.08	112.41

[1]No samples were collected in August 1977.

Table 8. Average biomass ($\bar{x}$) and standard deviation (s) of live and standing dead plant shoots and total plant biomass (g/m^2) in the fertilized *J. roemerianus* community in Alabama.

Date	Live		Dead		Total Biomass	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
2-17-77[2]	579.0	104.0	1254.0	170.0	1832.6	267.1
4-20-77	710.0	89.0	1239.0	170.0	1948.5	248.3
5-19-77	586.5	254.5	878.2	456.0	1730.7	449.2
6-22-77	379.5	98.2	1357.08	287.1	1736.6	356.3
7-27-77	663.6	114.4	1193.0	452.5	1856.6	485.4
8[3]	-	-	-	-	-	-
9-07-77	442.3	130.1	1117.0	211.8	1559.4	219.5
11-28-77	379.2	111.5	857.2	207.0	1236.4	308.4
2-17-78	311.83	132.37	796.44	220.47	1108.27	321.45
3-15-78	271.95	111.67	728.73	152.26	1000.68	160.79
4-19-78	374.5	139.93	969.23	453.36	1343.73	574.79
5-24-78	341.31	78.6	632.	98.57	973.31	143.92
6-28-78	643.07	157.26	493.29	168.67	1136.35	206.46
7-27-78	803.16	296.76	487.81	112.19	1290.97	317.64
9-01-78	537.14	76.59	634.64	127.24	1207.78	175.99
10-06-78	637.76	70.4	596.72	87.44	1236.52	123.56
12-05-78	704.57	164.33	508.29	209.75	1212.86	369.55

[1]Fertilized with 7.1 kg 13-13-13 per 100 m^2 on February 14, 1977, and 13.6 kg NH_4NO_3 (33% N) per 100 m^2 on February 18, 1978.

[2]Pretreatment samples.

[3]No samples collected in August 1977.

Table 9. Mean biomass and standard deviation of live and dead shoots and total plant biomass (g/m^2) in the Burned Alabama *Juncus roemerianus* community.

	LIVE		DEAD		TOTAL BIOMASS	
DATE	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S
2-17-77	648.0	46.0	1270.0	91.0	1917.6	121.9
4-20-77	159.0	19.0	210.0	139.0	369.1	156.8
5-19-77	163.1	101.7			163.1	101.7
6-22-77	280.5	73.6	145.8	41.6	426.3	100.3
7-27-77	354.9	92.3	124.7	120.5	479.6	202.8
8-NONE						
9-7-77	480.12	86.9	171.9	75.6	652.1	100.3
11-28-77	529.2	77.4	112.6	43.4	641.9	110.2
2-15-78	494.47	69.82	230.01	25.73	724.49	85.08
3-15-78	496.92	110.84	169.36	48.08	666.28	154.07
4-19-78	611.05	121.23	225.23	40.18	836.29	147.77
5-24-78	519.22	84.53	523.58	66.33	1042.8	122.83
6-28-78	467.43	110.29	230.13	73.15	697.57	174.11
7-27-78	607.05	128.28	376.27	74.92	983.32	170.96
9-01-78	607.6	83.39	365.48	61.41	973.08	106.64
10-06-78	464.07	46.07	491.44	52	955.5	78.14
12-05-78	519.41	129.6	456.45	216.22	975.86	341.74

Table 10. Mean biomass and standard deviation of live and dead shoots and total plant biomass (g m^2) in the Cut Alabama *Juncus roemerianus* community.

	LIVE		DEAD		TOTAL BIOMASS	
DATE	$\overline{X}$	S	$\overline{X}$	S	$\overline{X}$	S
2-17-77	550.0	102.0	1405.0	328.0	1955.1	422.3
4-20-77	94.0	34.0	222.0	60.0	315.3	82.1
5-19-77	227.49	60.6			227.49	60.6
6-22-77	283.9	73.0	156.3	86.7	440.2	85.5
7-26-77	437.32	73.14	70.0	18.4	507.3	75.3
8-NONE						
9-07-77	354.0	37.9	79.3	15.5	433.3	50.1
11-28-77	440.3	56.3	210.1	31.3	650.4	66.8
2-15-78	264.15	105.83	1826.71	575.39	2090.86	605.93
3-15-78	8.85	7.81	415.45	80.46	424.3	82.95
4-19-78	64.77	14.25	555.72	85.46	620.49	80.27
5-24-78	156.51	34.7	-	-	-	-
6-28-78	233.34	72.69	-	-	-	-
7-27-78	213.74	50.05	13.25	6.51	226.99	51.53
9-01-78	207.14	24.86	16.4	7.04	223.54	24.78
10-06-78	333.0	65.64	130.56	30.04	463.55	93.97
12-05-78	392.75	85.55	137.29	29.47	530.03	107.34

Table 11. Average biomass ($\bar{x}$) and standard deviation (s) of live and standing dead shoots and total aboveground biomass (g/m^2) in the control *S. alterniflora* community in Alabama.

Date	Live $\bar{x}$	Live s	Dead $\bar{x}$	Dead s	Total Biomass $\bar{x}$	Total Biomass s
2-18-77	242.0	203.0	520.0	107.0	761.7	293.1
4-26-77	199.0		413.0	44.0	612.4	96.5
5-23-77	299.4	96.4	443.7	95.8	743.1	183.8
6-23-77	413.6	85.7	327.7	100.1	741.3	134.3
7-27-77	406.4	118.7	141.3	61.5	547.7	170.6
8[1]	-	-	-	-	-	-
9-12-77	162.8	67.9	155.4	27.3	318.2	58.6
11-29-77	86.1	71.4	272.6	53.7	358.7	92.6
2-16-78	309.69	78.07	197.01	55.32	506.69	74.30
3-17-78	205.67	48.72	384.9	107.38	590.57	101.85
5-02-78	231.55	93.27	246.61	80.96	478.16	141.89
6-14-78	351.86	113.93	174.17	30.24	526.03	128.58
6-26-78	271.07	31.48	102.98	40.43	374.05	63.19
8-01-78	514.59	50.67	87.21	25.83	601.8	59.27
9-09-78	473.05	34.23	94.77	40.37	567.81	56.46
10-09-78	680.8	102.28	50.4	14.32	731.2	105.72
12-07-78	641.61	119.27	79.58	36.2	721.19	124.8

[1]No samples were collected in August 1977.

Table 12. Average biomass ($\bar{x}$) and standard deviation (s) of live and standing dead shoots and total aboveground biomass (g/m^2) in the fertilized[2] *S. alterniflora* community in Alabama.

Date	Live $\bar{x}$	Live s	Dead $\bar{x}$	Dead s	Total Biomass $\bar{x}$	Total Biomass s
2-18-77[2]	234.0	187.0	445.0	148.0	679.2	108.6
4-26-77	234.0	35.0	378.0	46.0	611.9	50.8
5-23-77	265.9	97.4	439.1	182.2	705.0	240.2
6-23-77	384.7	249.8	262.3	90.1	713.7	216.6
7-27-77	407.4	134.9	171.5	66.3	575.9	162.2
8[1]	-	-	-	-	-	-
9-12-77	323.5	61.5	132.6	48.4	456.2	100.2
11-29-77	536.9	65.4	74.5	38.2	611.5	39.4
2-16-78	228.49	66.5	79.84	28.39	308.33	68.75
3-17-78	119.22	40.05	205.91	39.47	325.13	72.48
5-02-78	257.29	68.44	168.1	42.37	425.39	102.40
6-14-78	442.11	151.63	134.54	50.74	576.65	196.18
6-26-78	309.55	75.58	83.52	22.67	393.07	93.70
8-01-78	961.55	276.41	144.75	57.17	1106.3	322.34
9-09-78	1165.19	135.9	144.46	36.16	1309.65	152.61
10-09-78	1031.2	119.96	88.56	19.24	1119.76	110.68
12-07-78	469.03	126.62	118.54	33.9	587.57	106.85

[1]No samples were collected in August 1977.

Table 13. Mean biomass and standard deviation of live and dead shoots and total aboveground biomass (g/m^2) in the Burned *Spartina alterniflora* community.

	LIVE		DEAD		TOTAL BIOMASS	
DATE	$\overline{X}$	S	$\overline{X}$	S	$\overline{X}$	S
2-18-77	335.0	185.0	616.0	148.0	950.9	317.8
4-26-77	117.0	26.0	354.0	66.0	471.6	88.8
5-23-77	118.1	28.2	192.8	51.9	310.9	59.3
6-23-77	259.1	79.6	257.9	15.7	517.0	79.3
7-27-77	429.0	82.9	176.1	85.3	605.1	58.4
8-NONE						
9-12-77	208.7	43.7	35.9	28.0	244.6	71.1
11-29-77	251.21	37.8	128.5	49.9	379.8	38.1
2-16-78	234.05	67.94	120.71	23.44	354.93	62.70
3-17-78	170.49	46.29	312.19	89.98	482.69	126.17
5-02-78	319.93	74.46	281.73	98.45	601.67	143.31
6-14-78	275.76	81.04	87.78	41.9	363.54	114.75
6-26-78	461.43	93.33	64.32	42.37	525.75	80.01
8-01-78	424.58	39.36	131.12	57.14	555.7	85.28
9-09-78	421.91	43.35	192.65	36.52	614.55	46.78
10-09-78	680.8	102.28	50.4	14.32	731.2	105.72
12-07-78	525.09	113.66	65.98	37.66	591.07	132.56

Table 14. Mean biomass and standard deviation of live and dead shoots and total aboveground biomass (g/m^2) in the Cut *Spartina alterniflora* community.

	LIVE		DEAD		TOTAL BIOMASS	
DATE	$\overline{X}$	S	$\overline{X}$	S	$\overline{X}$	S
2-18-77	366.0	184.0	508.0	124.0	874.1	255.8
4-26-77	96.0	30.0	99.0	131.0	194.3	132.0
5-23-77	134.7	63.6	134.7	63.6	134.7	63.6
6-23-77	209.7	58.2	47.13	23.04	256.8	60.8
7-27-77	220.5	53.6			220.5	53.6
8-NONE						
9-12-77	190.36	87.2			190.36	87.2
11-29-77	98.8	32.8	34.6	14.6	133.3	40.5
2-16-78	124.55	22.28	63.26	15.94	187.81	22.14
3-17-78	13.49	4.3	-	-	-	-
5-02-78	76.87	11.07	-	-	-	-
6-14-78	264.76	82.03	-	-	-	-
8-01-78	510.37	46.38	-	-	-	-
9-09-78	508.41	33.47	-	-	-	-
10-09-78	675.2	158.96	-	-	-	-
12-07-78	684.07	124.98	-	-	-	-

Table 15. Average biomass ($\bar{x}$) and standard deviations (s) of live and standing dead plant shoots, total litter, number of minor species, and total live biomass (g/m^2) of all species in the control S. *cynosuroides* community.

Date	Live $\bar{x}$	Live s	Dead $\bar{x}$	Dead s	Litter $\bar{x}$	Litter s	Assoc. Minor Spp. $\bar{x}$ no.	Total Live Biomass of All Species $\bar{x}$	Total Live Biomass of All Species s
2-14-77[1]	0	0	2172.6	426.4	785.4	163.0	0.8	120.7	152.3
4-27-77	376.3	110.3	1218.0	498.5	864.0	111.9	0.5	397.7	95.7
5-25-77	700.3	311.5	1485.3	621.5	988.7	93.8	0.8	865.3	291.6
6-29-77	1220.0	598.5	1656.7	318.9	1076.0	143.4	0.5	1279.7	557.8
7-29-77	1210.0	400.1	1122.7	122.6	792.7	148.9	0	1210.0	400.1
8-26-77	1072.0	300.0	1160.0	138.3	767.4	184.3	1.5	1557.3	350.6
9-17-77	1035.3	360.0	1014.7	282.2	1137.4	204.5	0.5	1122.7	345.9
11-26-77	0	0	1806.7	221.3	804.1	188.1	0.2	0.7	1.6
2-18-78[1]	0	0	1855.3	64.94	1437.3	50.50	0	0	0
4-23-78	228.7	20.30	279.3	86.06	1235.3	89.78	0.3	232.7	83.27
5-27-78	498.7	44.49	1141.3	48.32	1202.7	64.22	1.0	766.0	178.97
6-24-78	790.0	47.75	928.0	75.74	1092.7	67.40	1.0	1219.3	111.07
7-28-78	1296.7	28.0	990.7	92.4	883.3	25.8	1.0	1927.3	214.74
8-26-78	943.3	77.6	1766.6	147.3	1400.00	61.8	1.0	1298.7	285.54
9-22-78	1660.6	78.1	1426.6	106.3	1764.0	60.8	0.0	1660.67	312.34
10-28-78	1203.3	43.8	1341.6	76.6	1296.7	41.3	0.5	1360.67	264.02
11-26-78	581.3	41.5	2680.7	162.6	1369.3	92.7	0.2	606.0	171.52
12-16-78	206.0	61.3	2376.0	134.2	1342.0	172.0	0.7	354.67	68.57

[1]0 means no living plants during this winter month.

Table 16. Average biomass ($\bar{x}$) and standard deviation (s) of live and standing dead plant shoots, total litter, number of minor species, and total live biomass (g/m^2) of all species in two fertilized[1] *S. cynosuroides* communities.

Date	Live $\bar{x}$	Live s	Dead $\bar{x}$	Dead s	Litter $\bar{x}$	Litter s	Assoc. Minor Spp. $\bar{x}$ no.	Total Live Biomass of All Species $\bar{x}$	Total Live Biomass of All Species s
2-14-77[2]	0	0	999.3	366.2	662.7	113.9	1.2	153.3	140.3
4-23-77	180.7	80.1	1247.3	433.6	621.4	167.9	1.7	349.0	98.2
5-25-77	897.3	320.9	1259.0	273.0	758.0	249.7	0.5	901.0	318.7
6-29-77	1127.3	257.4	1096.0	458.3	682.1	138.9	1.3	1342.0	505.7
7-28-77	969.3	214.3	1150.7	333.7	758.1	186.0	2.2	1205.3	206.1
8-26-77	958.0	297.8	884.0	215.0	559.4	108.5	1.5	1149.3	485.0
9-17-77	769.3	245.3	900.0	191.2	1014.1	130.0	2.2	1095.3	392.6
11-26-77	0	0	1236.7	375.6	574.7	64.3	0.7	220.7	219.8
2-18-78[2]	0	0	1436.0	138.77	1001.3	30.12	0.5	10.33	19.28
4-23-78	238.7	9.29	1014.7	59.45	776.0	23.91	0.2	240.0	34.87
5-27-78	609.3	98.65	1417.3	137.43	712.7	68.20	2.3	1050.0	532.10
6-24-78	1316.0	91.89	1290.0	40.09	1260.0	54.26	0.3	1323.3	371.81
7-28-78	2070.7	113.8	976.7	87.1	879.3	55.4	0.0	2070.7	455.11
8-26-78	1536.6	107.1	1268.6	61.0	972.0	72.9	0.2	1652.0	516.32
9-22-78	2344.0	90.9	1481.3	62.1	1494.6	104.6	0.5	2366.0	346.80
10-28-78	1638.0	128.6	1649.3	66.1	1494.6	79.9	0.0[3]	1638.0	514.33
11-26-78	667.3	101.9	2717.3	221.2	1361.3	51.0	0.3	705.33	523.55
12-16-78	257.3	22.4	2842.0	74.2	1039.3	35.4	0.0[3]	257.3	89.43

[1]Fertilized with 7.1 kg 13-13-13 per 10 m^2 on February 14, 1977; 13.6 kg NH_4NO_3 (33% N) per 10 m^2 on February 18, 1978.

[2]Pretreatment sample; 0 means no live *Spartina* during this winter month.

[3]No minor species collected.

Table 17. Average biomass ($\bar{x}$) and standard deviation (S) of live and standing dead plant shoots, total litter, number of minor species, and total live biomass (g/m^2) of all species in the Burn I[1] *S. cynosuroides* community.

Date	Live $\bar{x}$	Live S	Dead $\bar{x}$	Dead S	Litter $\bar{x}$	Litter S	Assoc. Minor Spp. $\bar{x}$ no.	Total Live Biomass of All Species $\bar{x}$	Total Live Biomass of All Species S
2-14-77[2]	0	0	2028.0	757.2	597.7	93.9	1.0	65.3	58.3
4-19-77	446.7	515.7	0	0	409.4	99.8	1.5	609.7	105.8
5-24-77	839.7	305.8	0	0	449.4	179.2	1.7	1159.7	406.1
6-28-77	1480.0	389.0	57.0	47.1	483.4	89.0	0.7	1586.0	427.8
7-28-77	1229.3	490.6	47.3	13.5	444.8	87.8	2.5	1733.3	374.1
8-26-77	1303.7	435.0	61.0	57.1	487.4	81.7	0.8	1717.7	465.2
9-17-77	1419.3	552.7	34.0	40.6	826.7	237.1	0.5	1641.3	434.5
11-26-77	0	0	1085.3	223.7	656.0	94.6	0.8	147.4	204.5
12-20-77	0.7	1.6	1102.7	281.8			0.5	45.3	78.4
2-18-78[2]	0	0	1055.3	124.99	1678.7	65.69	0	0	0
4-23-78	376.7	27.00	113.3	27.45	296.7	53.60	1.3	484.00	103.69
5-27-78	817.3	58.30	37.3	8.14	188.0	14.98	2.2	982.33	161.47
6-24-78	1553.3	66.38	31.3	1.33	404.7	81.38	1.2	1883.33	385.94
7-28-78	1284.0	134.2	70.0	12.1	480.7	40.4	2.0	1922.7	431.90
8-26-78	976.7	47.9	934.0	108.1	414.6	19.8	1.3	1478.0	305.14
9-22-78	1944.6	124.4	216.0	31.2	592.0	21.2	0.8	2398.67	568.32
10-28-78	549.3	80.6	616.7	69.4	281.3	12.7	1.6	1057.3	466.60
11-26-78	221.3	36.1	1954.0	128.5	552.7	39.5	0.8	558.7	321.02
12-16-78	146.0	12.4	1472.7	44.1	618.0	21.8	1.2	354.0	251.90

[1]Burned February 14, 1977 and reburned February 18, 1978.

[2]Preburn sample; 0 means no living plants during this winter month.

Table 18. Average biomass ($\bar{x}$) and standard deviation (S) of live and standing dead plant shoots, total litter, number of minor species, and total live biomass (g/m^2) of all species in the Burn II[1] *S. cynosuroides* community.

Date	Live		Dead		Litter		Assoc. Minor Spp.	Total Live Biomass of All Species	
	$\bar{x}$	S	$\bar{x}$	S	$\bar{x}$	S	$\bar{x}$ no.	$\bar{x}$	S
2-18-78[2]	0	0	1849.3	217.07	1069.3	53.66	0	0	0
4-23-78	394.0	119.20	14.0	8.57	608.7	32.51	0.3	408.0	202.78
5-27-78	1235.3	86.52	0	0	355.3	30.17	1.3	1504.0	319.41
6-24-78	1472.7	113.07	44.7	4.27	586.7	37.01	0.5	1793.3	355.84
7-28-78	1922.7	181.4	61.3	11.3	412.0	34.9	1.0	2322.67	620.75
8-26-78	1480.0	95.5	760.0	169.1	864.6	22.7	0.2	1508.00	389.90
9-22-78	2211.3	84.8	232.0	23.2	556.0	88.1	0.5	2486.00	446.03
10-26-78	506.7	74.4	881.3	109.3	726.7	34.9	1.6	1014.0	348.63
11-26-78	248.7	34.1	1518.0	128.5	588.7	41.7	0.8	800.67	395.52
12-16-78	112.7	11.5	1561.3	69.1	730.0	75.5	1.2	285.33	135.73

[1] Burned February 18, 1978

[2] Preburn sample; 0 means no live *Spartina* during this winter month

Table 19. Average biomass ($\overline{x}$) and standard deviation (S) of live and standing dead plant shoots, total litter, number of minor species, and total live biomass (g/m^2) of all species in the Clipped I[1] *S. cynosuroides* community.

Date	Live $\overline{x}$	Live S	Dead $\overline{x}$	Dead S	Litter $\overline{x}$	Litter S	Assoc. Minor Spp. $\overline{x}$ no.	Total Live Biomass of All Species $\overline{x}$	Total Live Biomass of All Species S
2-14-77[2]	0	0	989.0	391.3	521.4	112.6	1.7	156.3	137.4
4-19-77	212.7	81.4	0	0	62.8	10.3	3.0	531.3	79.6
5-24-77	867.0	281.4	0	0	78.8	17.8	2.3	1144.0	348.3
6-28-77	1077.3	158.1	20.0	16.0	363.7	103.1	1.7	1371.7	178.3
7-28-77	935.3	265.3	49.7	39.9	273.4	141.9	2.5	1575.3	359.8
8-26-77	1042.0	328.8	79.0	44.9	507.4	72.6	1.7	1578.0	402.0
9-17-77	1160.0	308.4	47.3	33.6	258.0	48.3	0.8	1549.3	577.0
11-26-77	0.7	1.6	1178.7	274.4	394.0	69.9	0.8	291.4	325.5
2-18-78[2]	0	0	1144.7	67.36	324.7	14.30	0	0	0
4-23-78	192.0	2.78	0	0	114.7	15.92	2.2	309.33	127.85
5-27-78	753.3	52.74	0	0	48.7	5.23	1.8	1007.33	198.08
6-24-78	830.7	57.67	96.7	16.30	622.7	133.96	2.0	1265.33	455.30
7-28-78	1014.0	94.4	82.4	5.4	174.0	18.2	3.0	1344.0	321.69
8-26-78	938.0	57.1	654.6	95.6	189.3	24.1	1.6	1084.67	301.50
9-22-78	1591.3	46.4	224.0	43.3	416.0	22.0	1.7	1961.3	381.81
10-28-78	511.3	60.6	524.0	49.1	168.7	6.4	1.5	748.67	177.38
11-26-78	312.0	27.5	1104.0	103.3	360.0	25.1	1.3	510.0	138.00
12-16-78	157.0	23.4	1140.7	98.1	139.3	5.4	2.0	767.33	641.14

[1]Cut February 1 1977 and recut February 18, 1978.

[2]Precut sample; 0 means no live *Spartina* during this winter month.

Table 20. Average biomass ($\bar{x}$) and standard deviation (S) of live and standing dead plant shoots, total litter, number of minor species, and total live biomass (g/m^2) of all species in the Clipped II[1] S. cynosuroides community.

Date	Live		Dead		Litter		Assoc. Minor Spp.	Total Live Biomass of All Species	
	$\bar{x}$	S	$\bar{x}$	S	$\bar{x}$	S	$\bar{x}$ no.	$\bar{x}$	S
2-18-78[2]	0	0	1024.0	115.47	482.0	22.46	0.2	1.3	3.27
4-23-78	501.3	19.98	0	0	368.7	23.93	1.0	548.67	121.10
5-27-78	1108.0	74.27	0	0	341.3	53.82	0.5	1263.33	391.24
6-24-78	1318.7	102.18	44.00	7.87	401.3	34.55	0.8	1658.0	263.52
7-28-78	2858.0	142.0	0.0	0.0	380.0	13.8	0.0	2858.0	567.68
8-26-78	1044.6	117.8	891.3	78.1	275.3	10.9	0.5	1350.0	385.59
9-22-78	1151.3	30.1	408.1	68.5	383.3	13.9	1.2	1740.67	339.24
10-28-78	909.3	80.0	1232.7	113.8	442.7	23.6	0.3	920.0	304.66
11-26-78	282.7	30.97	1124.7	109.6	192.7	7.0	1.3	898.7	313.57
12-16-78	232.0	28.5	1346.7	58.5	-	-[3]	2.0	301.33	101.97

1 Cut February 18, 1978

2 Precut sample

3 Sample was lost due to fire in drying oven

Table 21. Average biomass and standard deviation of live and standing dead shoots, total litter, and the total live plant shoots (g/0.1 m^2) in the *S. patens* community.

	Live		Dead		Litter		Assoc. Minor Species	Total Live Biomass (All Species)	
Date	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$ no.	$\bar{x}$	s
2-15-77	125.3	48.2	790.0	331.7	86.0	32.6	0.2	144.0	59.5
4-27-77	68.7	33.0	148.7	55.2	6.7	4.1	0	68.7	33.0
5-25-77	91.3	26.2	33.3	26.0	18.0	13.6	0	91.3	26.2
6-29-77	119.7	29.0	92.3	33.8	161.0	92.0	0	119.7	29.0
7-29-77	83.7	63.6	26.7	28.8	4.0	0.02	0.5	91.7	60.6
8-26-77	140.7	43.7	73.3	34.3	9.7	5.1	0.5	145.3	42.3
9-17-77	78.5	28.9	54.0	25.6	19.4	47.4	0.7	89.2	26.9

Table 22. Average biomass and standard deviation of live and dead shoots and total biomass (g/m²) in the *D. spicata* community.

Date	Live		Dead		Total Biomass	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
2-21-77	97.0	32.0	872.0	123.0	968.3	131.3
4-27-77	94.0	29.0	292.0	60.0	386.1	72.2
5-24-77	130.8	19.3	376.9	96.2	507.8	97.4
6-21-77	203.7	29.8	470.2	193.7	673.8	174.6
7-25-77	150.9	30.9	295.9	28.5	446.8	52.0
8-25-77	142.9	21.7	324.4	62.1	467.3	71.5
9-14-77	127.5	29.5	351.8	74.9	479.2	96.9
11-30-77	130.2	29.7	239.8	93.6	370.0	120.8

Table 23. Standing crop of belowground biomass (kg/m^2) in the Mississippi *J. roemerianus* marsh at the 0-10 cm and the 11-20 cm depth levels.

Date	Control	Burned	Clipped	Fertilized	$\bar{x}$
		0-10 cm Depth Level			
2-15-77	3.24	2.99	3.44	2.86	3.13
4-27-77	3.00	3.57	3.62	3.53	3.43
5-25-77	2.46	3.30	2.67	3.28	2.93
6-29-77	3.88	4.00	3.91	3.06	3.71
7-29-77	2.24	3.81	3.72	3.57	3.33
8-26-77	2.84	2.74	3.79	3.54	3.23
9-17-77	3.88	2.88	3.03	4.14	3.48
11-26-77	2.86	3.09	3.63	3.79	3.34
		11-20 cm Depth Level			
2-15-77	2.42	2.64	2.37	2.81	2.56
4-27-77	2.90	3.00	2.57	2.64	2.78
5-25-77	2.46	2.67	2.66	3.23	2.76
6-29-77	2.53	2.80	2.43	2.70	2.62
7-29-77	2.30	2.52	2.48	2.84	2.54
8-26-77	2.23	3.06	2.78	2.75	2.70
9-17-77	2.23	2.52	1.96	2.99	2.43
11-26-77	2.57	2.72	2.79	2.50	2.65

Table 24. Standing crop of belowground biomass (kg/m^2) in the *S. cynosuroides* marsh in the 0-10 cm and 11-20 cm depth levels.

Date	Control	Burned	Clipped	Fertilized	$\bar{x}$
		0-10 cm Depth Level			
2-15-77	2.84	2.92	2.61	3.23	2.90
4-19-77	2.64	2.27	2.93	2.93	2.69
5-24-77	2.37	2.56	3.88	2.53	2.84
6-28-77	2.80	3.60	4.06	2.28	3.19
7-28-77	3.97	4.01	3.95	3.86	3.95
8-26-77	2.25	2.46	4.41	2.84	2.99
9-17-77	2.85	2.25	2.53	2.94	2.89
11-26-77	2.23	3.60	2.94	3.21	3.00
		11-20 cm Depth Level			
2-15-77	4.07	5.21	4.71	3.12	4.28
4-19-77	4.66	3.91	3.45	3.69	3.93
5-24-77	3.92	5.41	4.71	4.25	4.57
6-28-77	4.55	4.62	4.71	4.38	4.56
7-28-77	4.88	4.71	3.78	5.36	4.68
8-26-77	4.75	4.33	5.26	4.67	4.75
9-17-77	4.19	4.24	4.48	3.50	4.10
11-26-77	3.51	4.00	5.04	4.69	4.31

Table 25. Standing crop of belowground biomass (kg/m^2) in the Alabama _J. roemerianus_ marsh at the 0-10 cm and the 11-20 cm depth levels.

Date	Control	Burned	Clipped	Fertilized	$\bar{x}$
		0-10 cm Depth Level			
2-17-77	2.48	2.10	2.29	3.55	2.60
4-20-77	2.00	3.62	1.98	2.82	2.60
5-19-77	1.96	1.11	1.76	2.05	1.72
6-29-77	0.99	0.71	1.68	1.35	1.18
7-26-77	0.92	0.46	2.17	2.53	1.52
9-07-77	1.70	1.90	0.39	1.99	1.49
11-28-77	2.18	2.34	1.69	2.60	2.20
		11-20 cm Depth Level			
2-15-77	1.03	2.13	2.48	2.22	1.97
4-20-77	1.32	1.81	2.48	3.45	2.27
5-19-77	1.37	1.19	2.47	2.57	1.90
6-29-77	1.23	1.32	2.67	0.68	1.48
7-26-77	1.51	2.39	4.03	2.93	3.72
9-07-77	2.13	3.85	1.53	2.11	2.41
11-28-77	1.01	1.28	0.38	1.03	0.93

Table 26. Standing crop of belowground biomass (kg/m^2) in the *S. alterniflora* marsh at the 0-10 cm and the 11-20 cm depth levels.

Date	Control	Burned	Clipped	Fertilized	$\bar{x}$
			0-10 cm Depth Level		
2-18-77	2.38	2.05	2.48	2.57	2.37
4-26-77	2.85	2.19	1.85	2.81	2.42
5-23-77	2.36	2.46	2.70	3.75	2.82
6-29-77	2.63	1.57	1.91	3.13	2.31
7-27-77	2.93	2.50	2.77	3.86	3.02
9-12-77	2.85	2.59	2.41	2.42	2.57
11-29-77	1.45	2.19	3.79	1.72	2.29
			11-20 cm Depth Level		
2-18-77	3.10	1.34	1.48	1.05	1.75
4-26-77	4.01	1.65	2.69	1.95	2.57
5-23-77	3.65	1.58	1.46	1.96	2.16
6-29-77	3.72	1.98	1.51	1.59	2.20
7-27-77	1.95	3.40	2.40	1.94	2.43
9-12-77	2.25	3.07	2.17	2.09	2.40
11-29-77	2.64	2.91	2.52	2.09	2.54

Table 27. Standing crop of belowground biomass (kg/m^2) in the *S. patens* community in the 0-10 and 11-20 cm depth levels.

Date	0-10 cm Depth Levels	11-20 cm Depth Levels	Total
2-15-77	3.23	2.89	6.12
4-27-77	3.11	3.44	6.55
5-25-77	2.64	3.03	5.67
6-29-77	3.03	3.50	6.53
7-29-77	3.88	3.35	7.23
8-26-77	3.06	2.65	5.71
9-17-77	4.41	3.20	7.61

Table 28. Standing crop of belowground biomass (kg/m^2) in the *D. spicata* marsh at the 0-10 cm and 11-20 cm depth levels.

Date	0-10 cm Depth Levels	11-20 cm Depth Levels	Total
2-21-77	1.36	0.22	1.32
4-27-77	1.02	0.09	1.11
5-24-77	1.11	0.10	1.21
6-21-77	1.38	0.27	1.61
7-25-77	1.84	0.36	2.20
8-25-77	1.17	0.41	1.58
9-14-77	1.09	0.13	1.22
11-30-77	2.50	0.95	3.45

Table 29. Carbon (C), hydrogen (H), nitrogen (N), phosphorus (P), and energy value (Kcal/gAFDW) of live aboveground and belowground materials from the 0-10 and 11-20 cm levels in the Mississippi *J. roemerianus* Control plot.

Date	% C	% H	% N	% P	Kcal/gAFDW
		Aboveground Living Leaves and Stems			
2-15-77	46.381	6.511	0.715	0.082	4.815
4-26-77	44.875	6.585	0.726	0.077	4.593
5-25-77	46.683	6.044	0.704	0.078	4.571
6-29-77	44.954	6.072	0.410	0.072	4.746
7-29-77	45.438	6.296	0.685	0.080	4.554
8-26-77	45.826	6.485	0.811	0.078	4.882
9-17-77	44.011	5.899	0.802	0.079	4.884
11-26-77	44.483	6.061	0.961	0.078	4.884
		Belowground Roots and Rhizomes at 0-10 cm Depth Level			
2-15-77	43.963	5.493	0.696	0.085	4.811
4-27-77	42.045	5.852	0.551	0.085	4.780
5-25-77	43.161	5.679	0.549	0.074	4.705
6-29-77	40.830	5.414	0.512	0.058	4.844
7-29-77	40.572	5.520	0.503	0.077	4.863
8-26-77	41.731	5.466	0.500	0.078	5.070
9-17-77	39.537	4.890	0.518	0.075	5.119
11-26-77	41.999	5.278	0.396	0.074	4.982
		Belowground Roots and Rhizomes at 11-20 cm Depth Level			
2-15-77	42.628	5.547	0.513	0.078	3.845
4-27-77	44.590	5.749	0.417	0.071	4.729
5-25-77	39.866	5.638	0.498	0.069	4.850
6-29-77	42.468	5.343	0.354	0.074	5.134
7-29-77	38.210	5.184	0.533	0.072	5.038
8-26-77	41.961	5.069	0.644	0.071	5.277
9-17-77	43.539	5.034	0.661	0.072	5.249
11-26-77	41.242	5.044	0.664	0.072	5.328

Table 30. Carbon (C), hydrogen (H), nitrogen (N), phosphorus (P), and energy value (Kcal/gAFDW) of live aboveground and belowground materials from the 0-10 and 11-20 cm levels in the Mississippi J. roemerianus Fertilized plot.

Date	% C	% H	% N	% P	Kcal/gAFDW
		Aboveground Living Leaves and Stems			
2-15-77	46.381	6.511	0.715	0.082	4.781
4-27-77	45.523	6.178	0.984	0.088	4.535
5-25-77	44.953	5.983	0.796	0.083	4.415
6-29-77	44.414	5.906	0.465	0.082	4.681
7-29-77	44.121	6.362	0.637	0.083	4.644
8-26-77	45.710	6.165	0.760	0.079	4.672
9-17-77	42.475	5.988	0.491	0.074	4.835
11-26-77	42.162	6.081	0.666	0.077	4.801
		Belowground Roots and Rhizomes at 0-10 cm Depth Level			
2-15-77	43.963	5.493	0.696	0.085	4.729
4-27-77	44.092	5.816	0.490	0.085	4.767
5-25-77	39.432	5.798	0.477	0.082	4.613
6-29-77	39.188	5.187	0.402	0.081	4.885
7-29-77	40.231	5.638	0.432	0.075	4.844
8-26-77	39.148	5.294	0.544	0.083	5.076
9-17-77	37.598	5.069	0.367	0.077	4.987
11-26-77	40.882	5.244	0.512	0.077	4.956
		Belowground Roots and Rhizomes at 11-20 cm Depth Level			
2-15-77	42.628	5.547	0.513	0.078	5.147
4-27-77	43.624	5.935	0.547	0.075	4.695
5-25-77	39.330	5.772	0.478	0.067	5.026
6-29-77	40.912	4.942	0.708	0.066	5.063
7-28-77	41.575	5.537	0.511	0.070	4.827
8-26-77	42.587	5.261	0.513	0.072	5.193
9-17-77	44.461	5.287	0.672	0.070	5.117
11-26-77	44.550	5.337	0.467	0.069	5.241

Table 31. Carbon (C), hydrogen (H), nitrogen (N), phosphorous (P), and energy value (Kcal/gAFDW) of live aboveground and belowground materials from the 0-10 and 11-20 cm levels in the Mississippi *J. roemerianus* Burned plot.

Date	% C	% H	% N	% P	Kcal/gAFDW
		Aboveground Living Leaves and Stems			
2-15-77	46.381	6.511	0.715	0.082	4.823
4-19-77	44.800	5.817	1.144	0.091	4.641
5-25-77	46.056	6.245	0.808	0.084	4.513
6-29-77	46.320	6.227	0.481	0.080	4.610
7-29-77	43.684	6.430	0.521	0.076	4.704
8-26-77	46.609	6.424	0.719	0.081	4.730
9-17-77	44.543	6.373	0.773	0.075	4.857
11-26-77	45.167	6.381	0.791	0.076	4.790
		Belowground Roots and Rhizomes at 0-10 cm Depth Level			
2-15-77	43.963	5.493	0.696	0.085	4.690
4-27-77	---	---	---	---	4.769
5-25-77	39.589	5.779	0.549	0.081	4.773
6-29-77	39.937	5.308	0.488	0.080	4.682
7-29-77	38.952	5.374	0.507	0.080	4.650
8-26-77	39.160	5.128	0.484	0.069	4.946
9-17-77	41.878	5.429	0.469	0.072	4.972
11-26-77	40.891	5.316	0.501	0.070	4.791
		Belowground Roots and Rhizomes at 11-20 cm Depth Level			
2-15-77	42.628	5.547	0.513	0.078	5.063
4-29-77	43.564	5.714	0.629	0.070	4.893
5-25-77	39.994	5.716	0.809	0.071	4.876
6-29-77	40.644	5.409	0.476	0.071	5.183
7-29-77	40.595	5.504	0.556	0.072	5.085
8-26-77	42.513	5.482	0.511	0.071	5.246
9-17-77	43.828	5.472	0.535	0.070	5.157
11-26-77	44.079	5.088	0.421	0.071	5.238

Table 32. Carbon (C), hydrogen (H), nitrogen (N), phosphorous (P), and energy value Kcal/gAFDW of aboveground and belowground materials from the 0-10 and 11-20 cm levels in the Mississippi _J. roemerianus_ Clipped plot.

Date	% C	% H	% N	% P	Kcal/gAFDW
		Aboveground Living Leaves and Stems			
2-15-77	46.381	6.511	0.715	0.082	4.796
4-27-77	44.232	6.152	1.083	0.088	4.658
5-25-77	44.964	6.010	0.682	0.085	4.586
6-29-77	46.475	5.857	0.466	0.081	4.669
7-29-77	43.833	6.324	0.730	0.078	4.706
8-26-77	45.826	6.485	0.811	0.078	4.800
9-17-77	45.008	6.120	0.856	0.080	4.830
11-26-77	44.248	6.044	0.558	0.078	4.921
		Belowground Root and Rhizomes at 0-10 cm Depth Level			
2-15-77	43.963	5.493	0.696	0.085	4.963
4-27-77	41.801	5.370	0.322	0.087	4.652
5-25-77	41.911	6.195	0.487	0.082	4.344
6-29-77	38.656	5.291	0.556	0.077	4.633
7-29-77	40.227	5.502	0.458	0.081	4.766
8-26-77	41.963	5.614	0.568	0.086	4.786
9-17-77	43.291	5.220	0.420	0.080	4.915
11-26-77	42.674	5.244	0.362	0.077	4.874
		Belowground Roots and Rhizomes at 11-20 cm Depth Level			
2-15-77	42.628	5.547	0.513	0.078	5.039
4-27-77	45.383	5.535	0.570	0.071	4.962
5-25-77	40.767	5.344	0.548	0.069	4.848
6-29-77	43.865	5.433	0.628	0.068	5.134
7-29-77	43.387	5.767	0.463	0.071	5.002
8-26-77	41.249	5.537	0.593	0.073	5.379
9-17-77	40.081	5.319	0.566	0.074	5.117
11-26-77	42.487	5.595	0.372	0.074	5.075

Table 33. Carbon (C), hydrogen (H), nitrogen (N), phosphorous (P), and energy value (Kcal/gAFDW) of live aboveground and belowground materials from the 0-10 and 11-20 cm levels in the Alabama _J. roemerianus_ control plot.

Date	% C	% H	% N	% P	Kcal/gAFDW
			Aboveground Living Leaves and Stems		
2-77	46.472	6.277	0.781	0.075	4.731
4-77	44.874	6.031	0.575	0.077	4.672
5-77	44.512	5.822	0.541	0.079	4.731
6-77	44.509	5.981	0.602	0.078	4.659
7-77	44.324	5.964	0.568	0.078	4.737
8-77	--	--	--	--	--
9-77	43.248	5.993	0.548	0.081	4.615
11-77	44.291	5.929	0.588	0.082	4.723
			Belowground Roots and Rhizomes at 0-10 cm Depth Level		
2-77	--	--	--	--	4.606
4-77	--	--	--	--	--
5-77	39.913	5.711	0.569	0.078	4.958
6-77	34.054	4.893	0.482	0.070	4.963
7-77	35.843	5.048	0.538	0.075	4.957
9-77	36.910	4.948	0.502	0.073	4.785
11-77	31.531	4.509	0.467	0.074	5.791
			Belowground Roots and Rhizomes at 11-20 cm Depth Level		
2-77	--	--	--	--	4.959
4-77	42.864	5.818	0.474	0.064	5.026
5-77	37.413	4.986	0.638	0.067	4.891
6-77	41.054	5.562	0.567	0.067	5.106
7-77	41.125	5.481	0.560	0.068	5.097
9-77	40.390	4.908	0.472	0.072	4.521
11-77	31.922	4.591	0.532	0.067	4.958

Table 34. Carbon (C), hydrogen (H), nitrogen (N), phosphorous (P), and energy value (Kcal/gAFDW) of live aboveground and belowground materials from the 0-10 and 11-20 cm levels in the Alabama J. roemerianus Fertilized plot.

Date	% C	% H	% N	% P	Kcal/gAFDW
		Aboveground Living Leaves and Stems			
2-77	--	--	--	--	4.735
4-77	44.549	6.006	0.605	0.083	4.681
5-77	44.386	5.830	0.515	0.080	4.750
6-77	43.367	6.083	0.764	0.077	4.529
7-77	43.037	6.139	0.669	0.077	4.734
8-77	--	--	--	--	--
9-77	43.964	5.918	0.656	0.079	4.805
11-77	43.413	5.776	0.551	0.083	4.759
		Belowground Roots and Rhizomes at 0-10 cm Depth Level			
2-77	--	--	--	--	4.696
4-77	42.462	5.733	0.548	0.074	4.955
5-77	40.767	5.854	0.648	0.073	4.924
6-77	--	--	--	--	4.869
7-77	40.078	5.395	0.617	0.072	5.161
9-77	36.629	4.793	0.506	0.072	5.060
11-77	38.519	5.093	0.555	0.069	5.021
		Belowground Roots and Rhizomes at 11-20 cm Depth Level			
2-77	--	--	--	--	5.237
4-77	--	--	--	--	5.201
5-77	38.068	5.125	0.833	0.068	4.907
6-77	40.470	5.248	0.513	0.069	5.349
7-77	39.328	4.971	0.539	0.067	5.496
9-77	36.073	4.527	0.608	0.078	5.519
11-77	--	--	--	--	5.040

Table 35. Carbon (C), hydrogen (H), nitrogen (N), phosphorous (P), and energy value (Kcal/gAFDW) of live aboveground and belowground materials from the 0-10 and 11-20 cm levels in the Alabama J. roemerianus Burned plot.

Date	% C	% H	% N	% P	Kcal/gAFDW
			Aboveground Living Leaves and Stems		
2-77	---	---	---	---	---
4-77	40.103	5.735	0.476	0.071	4.587
5-77	40.802	5.818	0.586	0.082	4.773
6-77	41.191	5.865	0.831	0.080	4.498
7-77	42.314	5.935	0.719	0.079	4.705
8-77	---	---	---	---	---
9-77	42.094	5.976	0.660	0.083	4.789
11-77	44.486	5.904	0.585	0.081	4.460
			Belowground Roots and Rhizomes at 0-10 cm Depth Level		
2-77	---	---	---	---	4.700
4-77	41.003	5.063	0.587	0.067	4.757
5-77	39.478	5.388	0.506	0.069	5.223
6-77	37.062	5.157	0.506	0.075	4.958
7-77	36.469	5.235	0.510	0.071	4.842
9-77	40.623	5.073	0.479	0.072	4.732
11-77	37.322	4.971	0.510	0.078	4.284
			Belowground Roots and Rhizomes at 11-20 cm Depth Level		
2-77	---	---	---	---	5.163
4-77	42.082	5.608	0.405	0.067	4.833
5-77	39.635	5.207	0.763	0.069	5.174
6-77	41.228	5.125	0.806	0.075	5.070
7-77	39.968	5.278	0.754	0.069	6.711
9-77	39.207	5.088	0.652	0.075	5.203
11-77	37.058	4.895	0.719	0.067	4.907

Table 36. Carbon (C), hydrogen (H), nitrogen (N), phosphorous (P), and energy value (Kcal/gAFDW) of live aboveground and belowground materials from the 0-10 and 11-20 cm levels in the Alabama *J. roemerianus* Clipped plot.

Date	% C	% H	% N	% P	Kcal/gAFDW
		Aboveground Living Leaves and Stems			
2-77	---	---	---	---	4.692
4-77	42.363	5.947	0.556	0.081	4.647
5-77	44.176	5.918	0.607	0.081	4.568
6-77	42.471	5.801	0.508	0.079	4.570
7-77	43.303	5.901	0.586	0.757	4.809
8-77	41.711	5.818	0.574	0.085	---
9-77	---	---	---	---	4.855
11-77	43.142	5.842	0.579	0.080	4.519
		Belowground Roots and Rhizomes at 0-10 cm Depth Level			
2-77	---	---	---	---	4.730
4-77	41.244	5.766	0.496	---	---
5-77	40.762	5.707	0.356	0.072	4.979
6-77	39.346	5.515	0.694	0.069	5.077
7-77	42.223	5.606	0.539	0.068	5.085
9-77	38.118	5.128	0.490	0.074	5.275
11-77	38.194	5.257	0.524	0.070	5.825
		Belowground Roots and Rhizomes at 11-20 cm Depth Level			
2-77	---	---	---	---	5.100
4-77	42.205	5.545	0.510	0.685	5.163
5-77	42.208	5.405	0.607	0.069	5.355
6-77	41.852	5.336	0.561	0.066	5.296
7-77	39.496	5.100	0.556	0.068	5.337
9-77	41.804	5.301	0.514	0.074	4.965
11-77	37.201	4.941	0.539	0.069	5.090

Table 37. Carbon (C), hydrogen (H), nitrogen (N), phosphorous (P), and energy value (Kcal/gAFDW) of aboveground and belowground materials from the 0-10 and 11-20 cm levels in the S. cynosuroides control plot.

Date	% C	% H	% N	% P	Kcal/gAFDW
		Aboveground Living Leaves and Stems			
2-15-77	--	--	--	--	--
4-19-77	39.791	6.317	0.795	0.089	4.568
5-25-77	43.013	5.861	0.971	0.090	4.534
6-28-77	40.343	5.778	0.597	0.074	4.427
7-28-77	41.991	5.879	0.572	0.077	4.566
8-26-77	42.894	6.030	0.468	0.746	4.584
9-17-77	42.644	6.086	0.485	0.069	4.616
11-26-77	43.420	5.996	0.742	0.070	4.415
		Belowground Roots and Rhizomes at 0-10 cm Depth Level			
2-15-77	43.241	5.556	0.531	0.066	4.677
4-19-77	40.270	5.266	0.734	0.075	4.677
5-25-77	39.842	5.771	0.484	0.070	4.851
6-28-77	34.071	4.579	0.405	0.069	5.043
7-26-77	37.480	5.343	0.491	0.071	4.468
8-26-77	33.661	4.436	0.431	0.073	4.716
9-17-77	37.084	4.992	0.503	0.073	4.796
11-26-77	37.987	4.976	0.658	0.072	4.678
		Belowground Roots and Rhizomes at 11-20 cm Depth Level			
2-15-77	39.307	5.162	0.376	0.069	4.698
4-19-77	39.693	5.261	0.445	0.068	4.990
5-25-77	34.628	5.131	0.511	0.069	4.582
6-28-77	32.883	4.284	0.411	0.070	5.031
7-28-77	39.885	5.374	0.634	0.067	4.746
8-26-77	36.139	4.914	0.406	0.068	4.928
9-17-77	37.109	4.936	0.591	0.072	4.985
11-26-77	38.617	4.950	0.567	0.070	4.891

Table 38 Carbon (C), hydrogen (H), nitrogen (N), phosphorous (P), and energy value (Kcal/gAFDW) of live aboveground and belowground materials from the 0-10 and 11-20 cm levels in the *S. cynosuroides* Fertilized plot.

Date	% C	% H	% N	% P	Kcal/gAFDW
			Aboveground Living Leaves and Stems		
2-15-77	--	--	--	--	--
4-19-77	41.030	6.084	0.865	0.092	4.539
5-25-77	43.130	6.140	0.578	0.081	4.585
6-28-77	42.586	5.994	0.538	0.074	4.435
7-28-77	41.225	5.882	0.326	0.082	4.499
8-26-77	41.654	6.151	0.523	0.073	4.622
9-17-77	--	--	--	--	4.664
11-26-77	41.389	6.079	0.517	0.072	4.452
			Belowground Roots and Rhizomes at 0-10 cm Depth Level		
2-15-77	43.241	5.556	0.531	0.066	4.831
4-19-77	42.812	5.567	0.710	0.076	4.646
5-25-77	38.681	5.087	0.529	0.068	4.788
6-28-77	40.125	5.442	0.622	0.076	4.694
7-28-77	38.043	5.282	0.527	0.073	4.768
8-26-77	35.043	4.622	0.484	0.070	4.456
9-17-77	39.748	4.798	0.445	0.072	4.885
11-26-77	39.257	4.929	0.669	0.072	4.785
			Belowground Roots and Rhizomes at 11-20 cm Depth Level		
2-15-77	39.307	5.162	0.376	0.069	4.716
4-27-77	--	--	--	--	4.744
5-25-77	37.753	5.539	0.390	0.070	4.750
6-28-77	37.379	4.975	0.569	0.071	4.694
7-28-77	41.068	5.560	0.340	0.067	4.874
8-26-77	39.317	5.182	0.409	0.071	4.717
9-17-77	35.506	4.610	0.425	0.069	4.851
11-26-77	39.029	5.287	0.457	0.072	4.920

Table 39. Carbon (C), hydrogen (H), nitrogen (N), phosphorous (P), and energy value (Kcal/gAFDW) of live aboveground and belowground materials from the 0-10 and 11-20 cm levels in the *S. cynosuroides* Burned plot.

Date	% C	% H	% N	% P	Kcal/gAFDW
		Aboveground Living Leaves and Stems			
2-15-77	---	---	---	---	---
4-19-77	41.468	6.000	0.718	0.086	4.645
5-25-77	40.180	6.352	0.468	0.076	4.491
6-28-77	41.765	5.932	0.433	0.082	4.503
7-28-77	41.781	5.990	0.479	0.074	4.577
8-26-77	44.212	6.159	0.485	0.071	4.615
9-17-77	42.836	6.042	0.628	0.073	4.616
11-26-77	42.580	6.121	0.752	0.072	4.505
		Belowground Roots and Rhizomes at 0-10 cm Depth Level			
2-15-77	43.241	5.556	0.531	0.066	4.620
4-19-77	37.015	4.791	0.509	0.075	4.800
5-25-77	38.295	5.300	0.432	0.069	4.963
6-28-77	27.608	3.948	0.267	0.069	4.636
7-28-77	39.639	5.483	0.436	0.071	4.514
8-26-77	33.870	4.422	0.504	0.073	4.618
9-17-77	39.036	5.363	0.483	0.072	4.570
11-26-77	39.029	5.287	0.457	0.072	4.691
		Belowground Roots and Rhizomes at 11-20 cm Depth Level			
2-15-77	39.307	5.162	0.376	0.069	4.687
4-19-77	41.231	5.194	0.453	0.069	4.728
5-25-77	41.189	5.334	0.331	0.069	4.670
6-28-77	38.617	5.206	0.448	0.069	4.665
7-28-77	41.841	5.742	0.644	0.067	4.820
8-26-77	40.976	5.440	0.473	0.070	4.723
9-17-77	40.234	5.423	0.408	0.071	4.770
11-26-77	40.068	5.165	0.486	0.071	4.871

Table 40. Carbon (C), hydrogen (H), nitrogen (N), phosphorous (P), and energy value (Kcal/gAFDW) of live aboveground and belowground materials from the 0-10 and 11-20 cm levels in the *S. cynosuroides* Clipped plot.

Date	% C	% H	% N	% P	Kcal/gAFDW
		Aboveground Living Leaves and Stems			
2-15-77	---	---	---	---	---
4-19-77	41.212	5.899	0.735	0.088	4.665
5-25-77	44.301	6.122	0.454	0.082	4.517
6-28-77	43.167	6.012	0.468	0.072	4.572
7-28-77	42.528	6.200	0.397	0.078	4.641
8-26-77	44.305	6.253	0.503	0.071	4.535
9-17-77	42.519	5.827	0.595	0.069	4.637
11-26-77	41.562	5.766	0.826	0.070	4.539
		Belowground Roots and Rhizomes at 0-10 cm Depth Level			
2-15-77	43.241	5.556	0.531	0.066	4.570
4-19-77	39.944	5.371	0.462	0.078	4.468
5-25-77	40.534	5.539	0.548	0.074	4.475
6-28-77	39.514	5.352	0.496	0.070	4.563
7-28-77	38.498	5.372	0.620	0.074	4.777
8-26-77	37.761	5.183	0.532	0.076	5.022
9-17-77	40.435	5.247	0.676	0.071	4.427
11-26-77	40.125	5.186	0.634	0.071	5.272
		Belowground Roots and Rhizomes at 11-20 cm Depth Level			
2-15-77	39.307	5.162	0.376	0.069	4.784
4-19-77	41.915	5.623	0.636	0.071	4.945
5-25-77	41.788	5.375	0.318	0.065	4.951
6-28-77	43.693	5.681	0.276	0.070	5.027
7-29-77	37.543	5.249	0.415	0.071	5.110
8-26-77	31.336	5.145	0.443	0.071	4.902
9-17-77	38.181	5.436	0.649	0.070	4.899
11-26-77	40.059	5.062	0.443	0.072	4.732

Table 41. Carbon (C), hydrogen (H), nitrogen (N), phosphorous (P), and energy value (Kcal/gAFDW) of live aboveground *S. alterniflora* and belowground materials from the 0-10 and 11-20 cm levels in the *S. alterniflora* Control Plot.

Date	% C	% H	% N	% P	Kcal/gAFDW
		Aboveground Living Leaves and Stems			
2-77	41.618	5.867	0.770	--	4.566
4-77	39.966	5.888	0.551	--	--
5-77	38.959	5.690	0.594	0.089	4.638
6-77	36.034	5.269	0.554	0.079	4.404
7-77	39.010	5.569	0.524	0.077	4.523
8-77	--	--	--	--	--
9-77	37.979	5.436	0.508	0.081	4.433
11-77	37.049	5.569	0.555	0.080	4.354
		Belowground Roots and Rhizomes at 0-10 cm Depth Level			
2-77	--	--	--	--	4.914
4-77	38.424	5.349	0.609	0.067	5.138
5-77	38.682	5.170	0.679	0.071	4.891
6-77	40.326	5.312	0.798	0.072	5.266
7-77	39.706	5.194	0.782	0.072	5.154
9-77	38.799	5.085	0.669	0.079	4.867
11-77	38.256	4.909	0.699	0.071	5.146
		Belowground Roots and Rhizomes at 11-20 cm Depth Level			
2-77	--	--	--	--	5.502
4-77	37.977	4.744	0.690	0.063	5.763
5-77	31.349	3.837	0.695	0.064	5.710
6-77	35.692	4.792	0.665	0.070	5.281
7-77	43.424	5.578	0.605	0.067	5.644
9-77	40.196	5.273	0.697	0.076	5.670
11-77	39.003	4.911	0.681	0.065	6.737

Table 42. Carbon (C), hydrogen (H), nitrogen (N), phosphorous (P), and energy value (Kcal/gAFDW) of live aboveground *S. alterniflora* and belowground materials from the 0-10 and 11-20 cm levels in the *S. alterniflora* Fertilized Plot.

Date	% C	% H	% N	% P	Kcal/gAFDW
		Aboveground Living Leaves and Stems			
2-77	--	--	--	--	4.617
4-77	40.462	5.811	0.578	0.090	4.630
5-77	39.925	5.519	0.644	0.088	4.669
6-77	36.411	5.286	0.576	0.080	4.623
7-77	39.656	5.628	0.584	0.076	4.599
8-77	--	--	--	--	--
9-77	37.995	5.577	0.592	0.078	4.591
11-77	38.657	5.487	0.544	0.080	4.593
		Belowground Roots and Rhizomes at 0-10 cm Depth Level			
2-77	--	--	--	--	4.466
4-77	36.378	4.871	0.446	0.067	4.917
5-77	38.213	4.997	0.701	0.070	5.375
6-77	39.840	5.485	0.637	0.071	5.089
7-77	38.525	5.304	0.745	0.070	5.253
9-77	37.327	5.193	0.631	0.082	4.977
11-77	38.272	4.988	0.544	0.080	5.949
		Belowground Roots and Rhizomes at 11-20 cm Depth Level			
2-77	--	--	--	--	5.269
4-77	36.717	5.733	0.634	0.067	5.286
5-77	37.022	4.945	0.501	0.071	5.278
6-77	41.932	5.663	0.798	0.073	5.376
7-77	39.558	5.377	0.549	0.073	5.420
9-77	38.853	5.069	0.730	0.083	5.151
11-77	38.194	4.895	0.623	0.066	6.733

Table 43. Carbon (C), hydrogen (H), nitrogen (N), phosphorous (P), and energy value (Kcal/gAFDW) of live aboveground and belowground materials from the 0-10 and 11-20 cm levels in the *S. alterniflora* Burned plot.

Date	% C	% H	% N	% P	Kcal/gAFDW
Aboveground Living Leaves and Stems					
2-77	---	---	---	---	4.599
4-77	37.490	5.472	1.133	0.098	4.431
5-77	38.968	5.543	0.845	0.087	4.547
6-77	40.309	5.421	1.089	0.074	4.450
7-77	39.160	5.474	0.722	0.079	4.623
8-77	---	---	---	---	---
9-77	38.666	5.334	0.674	0.080	4.737
11-77	37.984	5.205	0.770	0.081	4.580
Belowground Roots and Rhizomes at 0-10 cm Depth Level					
2-77	---	---	---	---	4.756
4-77	40.255	5.777	0.366	0.069	4.983
5-77	39.723	5.325	0.694	0.075	5.191
6-77	40.309	5.421	1.089	0.075	5.090
7-77	41.070	5.547	0.832	0.077	5.257
9-77	38.723	5.116	0.768	0.080	4.756
11-77	38.111	4.840	0.697	0.072	5.933
Belowground Roots and Rhizomes at 11-20 cm Depth Level					
2-77	---	---	---	---	5.155
4-77	38.226	5.053	0.645	0.066	5.188
5-77	32.971	4.369	0.664	0.069	5.440
6-77	---	---	---	---	5.522
7-77	36.094	5.155	0.651	0.069	5.192
9-77	36.387	4.758	0.738	0.078	5.516
11-77	35.566	4.643	0.646	0.064	6.036

Table 44. Carbon (C), hydrogen (H), nitrogen (N), phosphorous (P), and energy value (Kcal/gAFDW) of live aboveground and belowground materials from the 0-10 and 11-20 cm levels in the S. alterniflora Clipped plot.

Date	% C	% H	% N	% P	Kcal/gAFDW
		Aboveground Living Leaves and Stems			
2-77	---	---	---	---	4.577
4-77	39.310	5.739	0.723	0.093	4.572
5-77	38.816	5.591	0.646	0.089	4.698
6-77	36.825	5.437	0.576	0.084	4.503
7-77	37.756	5.543	0.543	0.773	4.615
8-77	---	---	---	---	---
9-77	36.973	5.512	0.610	0.076	4.721
11-77	36.975	5.334	0.589	0.076	4.610
		Belowground Roots and Rhizomes at 0-10 cm Depth Level			
2-77	---	---	---	---	4.646
4-77	38.259	5.382	0.512	0.069	4.925
5-77	41.026	5.476	0.768	0.075	4.921
6-77	40.203	5.415	0.734	0.069	4.881
7-77	39.247	5.385	0.727	0.067	4.959
9-77	38.667	5.195	0.687	0.077	4.753
11-77	38.895	4.924	0.612	0.060	5.074
		Belowground Roots and Rhizomes at 11-20 cm Depth Level			
2-77	---	---	---	---	4.856
4-77	37.362	4.870	0.517	0.674	5.779
5-77	37.880	4.966	0.508	0.069	5.282
6-77	40.642	5.360	0.782	0.070	5.577
7-77	40.414	5.609	0.624	0.071	5.391
9-77	37.779	5.052	0.578	0.073	5.854
11-77	37.901	4.797	0.534	0.064	5.232

Table 45. Carbon (C), hydrogen (H), nitrogen (N), phosphorous (P), and energy value (Kcal/gAFDW) of live aboveground and belowground materials from the 0-10 cm and 11-20 cm levels in the *S. patens* plot.

Date	% C	% H	% N	% P	Kcal/gAFDW
		Aboveground Living Leaves and Stems			
2-15-77	---	---	---	---	4.715
4-27-77	45.123	6.268	0.771	0.081	4.642
5-25-77	46.164	6.232	0.566	0.076	4.606
6-29-77	47.608	5.997	0.237	0.077	4.604
7-29-77	43.015	6.067	0.495	0.080	4.625
8-26-77	44.328	6.173	0.644	0.084	4.629
9-17-77	43.939	6.078	0.573	0.078	4.725
11-26-77	45.030	6.136	0.548	0.079	4.650
		Belowground Roots and Rhizomes at 0-10 cm Depth Level			
2-15-77	---	---	---	---	4.644
4-27-77	41.777	5.478	0.518	0.075	4.905
5-25-77	42.222	5.377	0.582	0.075	4.604
6-29-77	40.553	5.491	0.462	0.074	4.684
7-29-77	41.217	5.599	0.532	0.073	4.695
8-26-77	44.551	5.980	0.470	0.076	4.585
9-17-77	40.377	5.074	0.563	0.075	4.813
11-26-77	41.783	5.500	0.521	0.075	4.704
		Belowground Roots and Rhizomes at 11-20 cm Depth Level			
2-15-77	---	---	---	---	4.887
4-27-77	44.641	5.865	0.314	0.069	4.685
5-25-77	41.994	5.735	0.355	0.065	4.850
6-29-77	44.481	5.850	0.226	0.070	4.766
7-29-77	43.765	5.859	0.545	0.067	4.872
8-26-77	45.423	5.863	0.518	0.070	4.817
9-17-77	40.891	5.536	0.482	0.071	4.855
11-26-77	43.532	5.785	0.407	0.069	4.819

Table 46. Carbon (C), hydrogen (H), nitrogen (N), phosphorous (P), and energy value (Kcal/gAFDW) of live aboveground and belowground materials from the 0-10 and 11-20 cm levels in the D. spicata plot.

Date	% C	% H	% N	% P	Kcal/gAFDW
		Aboveground Living Leaves and Stems			
2-77	45.605	6.327	0.935	0.092	4.753
4-77	42.655	6.084	0.542	0.086	4.719
5-77	40.499	5.860	0.642	0.079	4.693
6-77	40.417	5.890	0.561	0.076	4.608
7-77	42.626	6.046	0.564	0.077	4.717
8-77	42.864	5.879	0.630	0.079	4.839
9-77	41.897	5.501	0.538	0.078	4.724
11-77	42.167	5.411	0.579	0.079	4.752
		Belowground Roots and Rhizomes at 0-10 cm Depth Level			
2-77	39.047	5.359	0.465	0.083	4.849
4-77	37.054	5.206	0.507	0.078	4.917
5-77	35.099	4.917	0.503	0.078	4.925
6-77	31.524	4.850	0.363	0.075	4.639
7-77	35.605	5.290	0.492	0.088	4.672
8-77	---	---	---	---	4.861
9-77	41.734	5.166	0.848	0.082	3.902
11-77	35.387	4.806	0.464	0.082	4.698
		Belowground Roots and Rhizomes at 11-20 cm Depth Level			
2-77	---	---	---	---	---
4-77	---	---	---	---	---
5-77	---	---	---	---	4.750
6-77	18.612	3.174	0.455	0.068	4.717
7-77	26.061	3.889	0.401	0.856	4.396
8-77	---	---	---	---	4.257
9-77	35.380	4.496	---	---	3.281
11-77	35.670	4.636	---	0.064	5.860

Table 47. Summary statistics and comparisons of means between the aboveground plant material, 0-10 cm root-rhizome material, and 11-20 cm root-rhizome material as determined through a 1-way ANOVA.

A. *J. roemerianus*

	μ1 Aboveground		μ2 0-10 cm		μ3 11-20 cm	P
Kcal/gAFDW	4.7114	≠	4.8198	≠	5.0329	0.0001
Carbon %	45.122	≠	41.201	=	42.246	0.0001
Nitrogen %	0.7244	=	0.5067	≠	0.5436	0.0001
Hydrogen %	6.220	≠	5.448	≠	5.445	0.0001
Phosphorous %	0.0804	≠	0.0786	≠	0.0717	0.0001

B *S. cynosuroides*

	μ1 Aboveground		μ2 0-10 cm		μ3 11-20 cm	P
Kcal/gAFDW	4.556	≠	4.719	≠	4.825	0.0001
Carbon %	42.205	≠	38.699	≠	39.126	0.0001
Nitrogen %	0.5896	≠	0.5272	=	0.4543	0.0001
Hydrogen %	6.035	≠	5.161	=	5.443	0.001
Phosphorous %	0.0715	=	0.0715	≠	0.0696	0.001

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FINAL REPORT

EVALUATION OF THE ECOLOGICAL ROLE OF MICROORGANISMS IN TIDAL MARSHES ON THE MISSISSIPPI AND ALABAMA GULF COAST

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INTRODUCTION

The primary emphasis of the first year of this program was an ecological survey of the microbial populations in the salt-marsh environment. Accordingly, in coordination with the de la Cruz-Hackney team and the Stout-Ivester team, litter bags were prepared for the decomposition studies, deployed in the field during the week of March 14-18, 1977, and monitored for one year.

In addition, preliminary studies were initiated to study the mechanics of decomposition in the marsh and the process of converting low-protein marsh grass into high-protein microbial biomass.

The major emphasis of the second year of this study was to determine the relative ecological role of the various microorganisms involved in the carbon cycle in the salt marsh environment, using both mixed and pure cultures. Two essentially pure stands of marsh grass were chosen for these studies: an old community of *Juncus roemerianus* located on St. Louis Bay, Mississippi, and a stand of *Spartina alterniflora* located on Dauphin Island, Alabama. These two sites were chosen because results from the first year of this program indicated significant differences in their benthic fauna and microflora.

LITERATURE REVIEW

The presence of over 2,000,000 hectares of salt marshes on the Gulf and southern Atlantic coast (de la Cruz, 1973), and their impact on overall estuarine and marine ecology and economy (Burkholder and Bornside, 1975; Fallon and Pfaender, 1976; Squiers and Good, 1974; and Valiela et al., 1975) dictate that more in-depth studies be conducted concerning the populations and dynamics involved in these systems.

The purpose of this phase of the study was to investigate the role and magnitude of microbial decomposition of organic detritus in Gulf Coast salt marshes. The most notable change in the marshes as a result of decomposition is the conversion of low-protein marsh grass into high-protein microbial biomass (Gosselink and Kirby, 1974). In a similar study conducted in Georgia, Teal (1962) has shown that (in a closed system) protein levels can double within 16 weeks. Since net primary productivity of marsh grass can be in excess of 2500 $g/m^2/yr$ (Odum and Fanning, 1973), this represents a major source of readily utilizable organic compounds for the estuarine ecosystem.

A computerized search of the literature revealed a negligible amount of information concerning the microbial aspects of this estuarine ecosystem. Hence, the need for the study hereinafter reported.

MATERIALS AND METHODS

MICROBIAL POPULATION STUDIES

Samples were returned to the laboratory for analysis on six occasions: April 30, May 27, August 1, September 23, November 29, 1977, and March 15, 1978. The samples were prepared by blending 10 g of detritus from the litter bags in 90 ml of water in an Eberbach stainless steel microblender (#8580) and making dilutions from the resulting suspension. Enumeration was accomplished using the standard spread-plate technique on four different media:

(1) Bacto-Plate Count Agar for total bacterial count;

(2) Bacto-Cooke Rose Bengal Agar for molds;

(3) Bacto-Potato Dextrose Agar for yeasts; and

(4) Sucrose Nitrate Agar for Actinomycetes.

All media contained an addition of 10 ppt Rila® Marine Mix to approximate natural estuarine salinity. Plates were incubated at room temperature for 5 days and colonies were counted using a Quebec counter.

DECOMPOSITION STUDIES

Preliminary decomposition studies were carried out using reverse triple Sohngen units. The reaction vessels contained 10 g of sterile marsh grass (*Juncus roemerianus* and *Spartina alterniflora* were used in this study) and were filled with synthetic sea salts. The reservoir bottles contained acid-water with phenol red as a pH indicator. The units were incubated at ambient temperature for two weeks and, upon termination, the gas evolved was analyzed on a Fisher Gas Partitioner Model 1200 gas chromatograph.

MIXED CULTURE DECOMPOSITION STUDIES

Mixed culture studies were carried out with both the *Spartina* and *Juncus*, using above ground shoots (cut into one inch segments) and rhizosphere material taken from litter bags retrieved during the first year of the project. The reaction vessels contained 10 g of the appropriate substrate and 40 ml of Dubos mineral salts medium (Dubos, 1928) amended with 10 ppt Rila® Marine Mix to approximate natural marine salinity. The inoculum consisted of 1 ml of an enrichment retained from the first year. The aerobic test bottles were then closed with serum stoppers and received no further pretreatment. For the anaerobic tests, the atmosphere of the bottles was replaced with a mixture of 5% CO_2, 30% N_2, and 65% Ar. The units were incubated at ambient temperature and the atmospheres were periodically monitored using a Fisher Gas Partitioner Model 1200 gas chromatograph.

PURE CULTURE DECOMPOSITION STUDIES

Pure culture studies were carried out on above ground Juncus and Spartina shoots, ground with a Thomas Grinder using a #40 mesh screen (pore size of 425μm). Both resulting powders were tested against 20 pure cultures isolated from the marsh during the first year of the project, under both aerobic and anaerobic conditions. The reaction vessels contained 1 g of the ground substrate and 10 ml of Dubos mineral salts medium amended with 10 ppt Rila® Marine Mix. The aerobic and anaerobic test vessels were prepared and their atmospheres tested as above. Additionally, the terminal carbohydrate content was monitored using the phenol-sulfuric acid method (Dubois, et al., 1956), and the terminal protein content was determined using the Bio-Rad® protein assay.

CELLULOSE DECOMPOSITION

Cellulose utilization was investigated using the 20 pure cultures described above. The reaction vessels contained 40 ml of Dubos mineral salts medium amended with 10 ppt Rila® Marine Mix and 0.5% Difco Bacto-Cellulose. The aerobic and anaerobic bottles were prepared and monitored as described above.

RESULTS AND DISCUSSION

MICROBIAL POPULATIONS

In general, all counts (Tables 1-4) were considerably higher than had been anticipated at the onset of the program - especially the above ground samples which were invariably higher than the corresponding underground samples. Secondly, it was noted that the counts of all 4 microbial groups from underground samples from Spartina alterniflora were lower than counts from the other species of marsh grass. In the case of the total bacterial counts and actinomycetes, counts were depressed from August through December in all 5 species, with an apparent recovery beginning by March. This trend was less pronounced where counts were lower at the beginning, i.e. for Spartina alterniflora, and the 10 cm depth samples for all species. Mold and yeast counts were highly erratic throughout the year, although a fall/winter depression was indicated in most cases. It should be noted that all counts were carried out under aerobic conditions, and, therefore, obligate anaerobes were not detected. This fact, along with the erratic nature of the counts and the variability of weather within a season, prevents the drawing of more specific conclusions.

ISOLATION OF PURE CULTURES

A total of 60 representative microorganisms were isolated and archived for possible later study, and preliminary work was completed for the cellulose degradation studies planned for the second year.

DECOMPOSITION STUDIES

The gas analyses for the decomposition studies demonstrated diversity between replicates, even of the same species of grass. All samples monitored (2 of Juncus and 3 of Spartina) demonstrated evolution of large quantities of CO_2, while three of the samples (1 Juncus and 2 Spartina) also produced large quantities of methane (indicative of anaerobic decomposition.)

TABLE 1

SUMMARY TABLE OF TOTAL PLATE COUNTS

(All counts per gram wet weight)

Above Ground	April	May	August	September	December	March
Juncus roemerianus (Ms.)	$1.7x10^{8}$	$9.2x10^{7}$	$7.7x10^{7}$	$6.3x10^{7}$	$1.3x10^{7}$	$8.4x10^{7}$
Spartina cynosuroides	$>3x10^{8}$	$2.3x10^{8}$	$5.7x10^{8}$	$1.0x10^{8}$	$4.6x10^{7}$	$3.7x10^{7}$
Spartina patens	$2.3x10^{8}$	$3.1x10^{8}$	$4.1x10^{8}$	$1.1x10^{8}$	$2.9x10^{8}$	$7.6x10^{7}$
Juncus roemerianus (Ala.)	$>3x10^{8}$	$2.2x10^{8}$	$3.1x10^{8}$	$2.3x10^{7}$	$1.1x10^{7}$	$1.5x10^{8}$
Spartina alterniflora	$>3x10^{8}$	$9.5x10^{8}$	$4.7x10^{8}$	$8.6x10^{6}$	$7.1x10^{7}$	$>3x10^{9}$
Distichlis spicata	$1.7x10^{7}$	*	$3.5x10^{8}$	$9.1x10^{7}$	$2.2x10^{8}$	$>3x10^{9}$
5 cm						
J. roemerianus (Ms.)	$5.9x10^{7}$	$6.0x10^{7}$	$3.8x10^{6}$	$3.4x10^{7}$	$7.9x10^{6}$	$2.8x10^{6}$
S. cynosuroides	$1.6x10^{8}$	$2.7x10^{8}$	$2.9x10^{7}$	$4.7x10^{6}$	$2.9x10^{7}$	$6.6x10^{6}$
J. roemerianus (Ala.)	$7.3x10^{7}$	$1.2x10^{8}$	$9.1x10^{7}$	$3.1x10^{7}$	$2.4x10^{7}$	$2.1x10^{8}$
S. alterniflora	$5.9x10^{6}$	$6.9x10^{6}$	$1.7x10^{7}$	$3.4x10^{6}$	*	$>3x10^{6}$

TABLE 1. (Cont'd)

Above Ground	April	May	August	September	December	March
	(All counts per gram wet weight)					
10 cm						
J. roemerianus (Ms.)	$4.2x10^6$	$8.9x10^6$	$1.4x10^7$	$1.3x10^7$	$1.7x10^6$	$6.4x10^6$
S. cynosuroides	$2.2x10^7$	$3.8x10^7$	$3.5x10^6$	$6.3x10^6$	$4.9x10^6$	$5.1x10^6$
J. roemerianus (Ala.)	$5.1x10^7$	$6.3x10^7$	$3.8x10^7$	$7.6x10^6$	$4.0x10^6$	$1.9x10^8$
S. alterniflora	$2.4x10^6$	$3.9x10^6$	$5.0x10^6$	$1.4x10^6$	*	$>3x10^6$

*Samples not received

TABLE 2

SUMMARY TABLE OF FUNGI COUNTS

	(All counts per gram wet weight)					
Above Ground	April	May	August	September	December	March
Juncus roemerianus (Ms.)	$>3x10^6$	$1.6x10^7$	$7.1x10^6$	$6.8x10^6$	$1.3x10^6$	$>3x10^6$
Spartina cynosuroides	$>3x10^6$	$1.5x10^7$	$4.7x10^7$	$3.1x10^6$	$1.0x10^6$	$8.3x10^5$
Spartina patens	$>3x10^6$	$3.3x10^7$	$2.8x10^7$	$2.5x10^7$	$9.1x10^7$	$1.1x10^7$
Juncus roemerianus (Ala.)	$5.5x10^5$	$8.0x10^6$	$9.8x10^6$	$1.2x10^5$	$1.9x10^5$	$9.4x10^5$
Spartina alterniflora	$6.5x10^5$	$1.4x10^7$	$5.9x10^6$	$3.0x10^4$	$5.7x10^4$	$9.9x10^4$
Distichlis spicata	$1.4x10^6$	*	$3.8x10^6$	$1.9x10^6$	$5.5x10^6$	$3.2x10^7$
5 cm						
J. roemerianus (Ms.)	$1.4x10^6$	$4.3x10^6$	$1.2x10^5$	$1.7x10^5$	$9.8x10^4$	$9.1x10^4$
S. cynosuroides	$>3x10^6$	$7.5x10^6$	$5.8x10^5$	$5.6x10^5$	$8.4x10^5$	$2.4x10^5$
J. roemerianus (Ala.)	$8.5x10^5$	$1.2x10^6$	$5.2x10^4$	$3.5x10^4$	$6.3x10^4$	$5.1x10^5$
S. alterniflora	$2.5x10^4$	$<3x10^4$	$9.7x10^4$	$5.3x10^3$	*	$6.4x10^5$

TABLE 2. (Cont'd)

Above Ground	April	May	August	September	December	March
	(All counts per gram wet weight)					
<u>10 cm</u>						
<u>J</u>. <u>roemerianus</u> (Ms.)	$7.1x10^5$	$1.1x10^6$	$1.5x10^5$	$4.3x10^4$	$1.1x10^5$	$2.3x10^4$
<u>S</u>. <u>cynosuroides</u>	$8.9x10^5$	$1.4x10^6$	$3.4x10^5$	$4.1x10^5$	$8.0x10^5$	$3.2x10^5$
<u>J</u>. <u>roemerianus</u> (Ala.)	$3.9x10^5$	$9.0x10^5$	$1.1x10^5$	$2.7x10^4$	$2.3x10^4$	$4.3x10^6$
<u>S</u>. <u>alterniflora</u>	$6.7x10^3$	$<3x10^4$	$5.3x10^3$	$1.2x10^4$	*	$6.2x10^5$

*Samples not received

TABLE 3

SUMMARY TABLE OF YEAST COUNTS

	(All counts per gram wet weight)				
Above Ground	April	May	August	December	March
Juncus roemerianus (Ms.)	$>3x10^6$	$1.4x10^7$	$9.3x10^5$	$8.7x10^4$	$1.7x10^4$
Spartina cynosuroides	$1.5x10^6$	$>3x10^6$	$4.1x10^6$	$2.8x10^4$	$1.6x10^4$
Spartina patens	$6.2x10^5$	$>3x10^6$	$9.7x10^6$	$8.3x10^6$	$>3x10^6$
Juncus roemerianus (Ala.)	$5.3x10^4$	$>3x10^6$	$3.5x10^6$	$8.9x10^3$	$<3x10^3$
Spartina alterniflora	$3.1x10^5$	$1.1x10^7$	$1.6x10^6$	$4.1x10^3$	$<3x10^3$
Distichlis spicata	$8.3x10^5$	*	$1.0x10^7$	$1.2x10^7$	$<3x10^3$
5 cm					
J. roemerianus (Ms.)	$4.2x10^4$	$2.0x10^6$	$6.1x10^4$	$4.9x10^4$	$2.7x10^4$
S. cynosuroides	$1.8x10^6$	$1.9x10^6$	$5.3x10^5$	$2.5x10^5$	$1.5x10^5$
J. roemerianus (Ala.)	$1.5x10^4$	$1.6x10^6$	$1.3x10^5$	$1.2x10^3$	$<3x10^3$
S. alterniflora	$5.6x10^3$	$2.0x10^4$	$7.4x10^4$	*	$3.6x10^4$

TABLE 3. (Cont'd)

			(All counts per gram wet weight)		
Above Ground	April	May	August	December	March
<u>10 cm</u>					
<u>J. roemerianus</u> (Ms.)	$2.2x10^5$	$1.2x10^6$	$2.5x10^4$	$8.8x10^3$	$2.6x10^3$
<u>S. cynosuroides</u>	$8.5x10^5$	$8.7x10^5$	$2.8x10^5$	$5.9x10^4$	$1.5x10^5$
<u>J. roemerianus</u> (Ala.)	$8.4x10^3$	$1.9x10^6$	$2.7x10^5$	$3.3x10^3$	$<3x10^3$
<u>S. alterniflora</u>	$<3x10^3$	$5.4x10^3$	$1.7x10^3$	*	$<3x10^3$

*Sample not received

TABLE 4

SUMMARY TABLE OF ACTINOMYCETES (SNA)

	(All counts per gram wet weight)					
Above Ground	April	May	August	September	December	March
Juncus roemerianus (Ms.)	$>3x10^6$	$2.6x10^7$	$1.8x10^7$	$4.0x10^5$	$3.6x10^5$	$>3x10^6$
Spartina cynosuroides	$>3x10^6$	$3.9x10^7$	$6.1x10^7$	$2.2x10^6$	$2.7x10^6$	$1.0x10^6$
Spartina patens	$>3x10^6$	$6.9x10^7$	$3.4x10^7$	$4.4x10^6$	$2.1x10^7$	$3.8x10^7$
Juncus roemerianus (Ala.)	$>3x10^6$	$9.3x10^7$	$1.5x10^8$	$8.9x10^4$	$8.9x10^4$	$1.6x10^7$
Spartina alterniflora	$>3x10^6$	$1.1x10^8$	$8.4x10^7$	$6.7x10^4$	$1.7x10^5$	$>3x10^7$
Distichlis spicata	$>3x10^6$	*	$1.1x10^8$	$5.2x10^5$	$4.4x10^4$	$>3x10^7$
5 cm						
J. roemerianus (Ms.)	$>3x10^6$	$8.9x10^6$	$1.0x10^5$	$1.0x10^5$	$3.6x10^5$	$3.5x10^6$
S. cynosuroides	$>3x10^6$	$5.2x10^7$	$4.7x10^6$	$8.7x10^5$	$4.0x10^6$	$3.2x10^6$
J. roemerianus (Ala.)	$>3x10^6$	$3.7x10^7$	$4.5x10^7$	$6.0x10^5$	$4.7x10^5$	$8.6x10^7$
S. alterniflora	$>3x10^6$	$8.5x10^5$	$4.6x10^6$	$3.1x10^4$	*	$>3x10^7$

TABLE 4. (Cont'd)

	(All counts per gram wet weight)					
Above Ground	April	May	August	September	December	March
10 cm						
J. roemerianus (Ms.)	$1.4x10^6$	$9.7x10^5$	$7.1x10^6$	$3.1x10^4$	$3.2x10^5$	$7.2x10^6$
S. cynosuroides	$2.2x10^6$	$2.9x10^6$	$8.4x10^5$	$3.4x10^5$	$5.1x10^5$	$4.1x10^5$
J. roemerianus (Ala.)	$>3x10^6$	$4.3x10^7$	$8.6x10^6$	$3.8x10^5$	$1.8x10^5$	$1.5x10^7$
S. alterniflora	$>3x10^6$	$6.3x10^5$	$5.2x10^5$	$1.3x10^4$	*	$>3x10^7$

*Sample not received

Studies were also carried out to develope a workable medium for isolation and enumeration of cellulolytic bacteria. The medium selected was a composite of the media reported by Dubos (1928) and by Sanborn (1926) containing (per liter): 0.5 g $NaNO_3$, 1.0 g K_2HPO_4, 0.5 g $MgSO_4 \cdot 7H_2O$, 0.5 g KCl, 0.01 g $FeSO_4 \cdot 7H_2O$, 5 g granulated cellulose, and 15 g agar, adjusted to a final pH of 8.4. In addition, a double pH indicator was added, containing 5 ml of a 0.5% aqueous solution of aniline blue and 5 ml of a 1.0% solution of rosalic acid in ethanol. This media allowed growth of easily countable colonies, accompanied by a readily detectable color change.

As expected, the detritus of both Juncus and Spartina was readily decomposed by the mixed culture enrichments (Table 5) over a period of 4 weeks. The rhizosphere material of the Spartina alterniflora was converted to CO_2 to a greater extent (both aerobically and anaerobically) than the other 3 systems. It should be noted here that, surprisingly, little or no methane was detected either from mixed or pure culture systems, but this could be due to the presence of nitrate, which has been shown to be inhibitory to methanogenesis (Zender, 1978).

The gas chromatographic data from the pure culture studies indicate that, with a few exceptions, all pure cultures tested readily decompose both the Juncus (Table 6) and the Spartina (Table 7), under both aerobic and anaerobic conditions. Further, protein production in 4 weeks reached as high as 2.2 mg protein/gram of substrate in the Juncus, and as high as 2.4 mg protein/gram of substrate for the Spartina. Pure culture studies indicate a wide range of decomposition rates, along with a high degree of variability in end products. Protein production ranges from 0–500 grams per Kg of grass decomposed (Table 8), depending on the culture.

Although only 4 of the 20 cultures tested demonstrated any appre-

Table 5

Mixed Culture Decomposition[1]

Substrate	Conditions	CO_2[2]	O_2[3]	CH_4[2]
Spartina above ground	Aerobic	15,687	3,756	37.5
	Anaerobic	8,801		>20
Spartina rhizosphere	Aerobic	27,919	3,964	>20
	Anaerobic	17,455		>20
Juncus above ground	Aerobic	16,755	3,948	103
	Anaerobic	7,696		>20
Juncus rhizosphere	Aerobic	16,387	3,948	253
	Anaerobic	7,844		>20

[1] All figures are the average of 4 tests.

[2] Expressed as μg of gas produced per gram of detritus

[3] Expressed as μg of gas utilized per gram of detritus

Table 6

Growth on Finely Ground Juncus

Culture	Conditions[1]	CO_2[2]	O_2[3]	Carbohydrate[4]	Protein[4]
C	A	30,933	12,412	250	87
	B	9,820		769	23
D	A	26,514	8,560	1,129	80
	B	7,365		118	23
E	A	27,987	8,774	384	58
	B	13,257		1,047	37
F	A	27,496	8,774	212	44
	B	0		900	44
G	A	30,442	10,272	547	65
	B	9,329		769	23
H	A	28,478	10,486	168	95
	B	11,784		428	10
I	A	22,095	7,490	709	58
	B	10,311		474	44
Z	A	19,149	4,280	64	58
	B	14,730		2,433	80
S-3	A	27,496	9,844	188	10
	B	982		451	58
S-4	A	26,023	7,918	2,081	80
	B	9,329		739	72
S-6	A	30,442	13,054	300	110
	B	14,239		24	47

Table 6. (Cont'd)

Culture	Conditions[1]	CO_2[2]	O_2[3]	Carbohydrate[4]	Protein[4]
S-7	A	23,077	10,486	168	30
	B	13,748		653	0
S-8	A	30,933	9,844	739	87
	B	13,748		573	47
S-11	A	12,275	4,280	341	87
	B	8,347		261	51
S-13	A	30,442	12,840	>6	110
	B	16,203		769	37
S-14	A	22,586	6,634	86	72
	B	10,802		164	30
222	A	28,969	8,560	34	30
	B	11,784		223	0
273	A	18,658	5,136	739	110
	B	11,293		1,366	58
275	A	26,514	10,700	599	87
	B	12,766		54	51
295	A	23,568	7,276	573	58
	B	19,640		212	0
Control				804	0

Table 7

Growth on Finely Ground Spartina

Culture	Conditions[1]	CO_2[2]	O_2[3]	Carbohydrate[4]	Protein[4]
C	A	33,388	13,268	96	80
	B	14,239		241	44
D	A	0	1,926	242	37
	B	14,730		1,420	3
E	A	29,460	7,276	547	51
	B	12,275		1,814	10
F	A	32,406	11,984	321	51
	B	10,802		362	65
G	A	0	4,494	406	51
	B	13,257		769	118
H	A	36,334	11,770	223	65
	B	11,784		866	16
I	A	36,334	13,268	522	44
	B	11,784		522	58
Z	A	14,730	4,494	24	95
	B	14,730		1,600	44
S-3	A	0	0	935	51
	B	9,329		1,420	30
S-4	A	21,113	3,852	428	37
	B	13,257		13	0
S-6	A	27,005	8,132	321	65
	B	16,203		428	58

Table 7. (Cont'd)

Culture	Conditions[1]	CO_2[2]	O_2[3]	Carbohydrate[4]	Protein[4]
S-7	A	0	1,926	769	118
	B	12,766		362	44
S-8	A	27,496	12,412	769	37
	B	0		573	30
S-11	A	23,568	8,346	547	65
	B	23,568		498	102
S-13	A	37,807	11,342	212	95
	B	982		96	65
S-14	A	39,280	11,128	225	10
	B	14,239		>6	65
222	A	34,370	13,268	1,009	51
	B	11,293		150	72
273	A	491	2,140	212	37
	B	7,856		250	10
275	A	31,915	13,054	164	44
	B	16,203		384	0
295	A	29,460	8,560	474	80
	B	10,311		522	0
Control				827	0

[1] A = Aerobic; B = Anaerobic

[2] Listed as µg of CO_2 produced per gram of substrate

[3] Listed as µg of O_2 utilized per gram of substrate

[4] Listed as µg/ml

TABLE 8

PURE CULTURE PROTEIN PRODUCTION

	Juncus		Spartina	
Culture	Aerobic*	Anaerobic*	Aerobic*	Anaerobic*
C	73.4	61.7	63.9	79.4
D	78.4	80.0	NA	5.1
E	55.6	73.4	47.2	24.2
F	43.6	NA	43.3	139.7
G	57.3	65.8	NA	188.1
H	85.2	24.3	49.0	38.4
I	68.9	105.4	33.6	118.5
Z	78.3	127.4	147.3	70.9
S-3	10.4	480.3	NA	81.7
S-4	79.8	169.4	47.6	0.0
S-6	91.7	84.8	64.0	90.2
S-7	36.0	0.0	NA	88.4
S-8	73.6	86.6	37.8	666.7
S-11	158.8	141.4	71.8	106.4
S-13	91.5	60.5	66.6	496.8
S-14	82.0	72.6	7.8	111.2
222	28.9	0.0	41.0	146.0
273	137.2	121.9	511.8	35.2
275	84.3	99.4	38.8	0.0
295	36.0	0.0	71.1	0.0

*All values expressed as grams of protein produced/kilogram of grass decomposed ciable cellulose utilization (as monitored by CO_2 production) all four were extremely active as shown on Table 9. Two cultures exhibited primarily aerobic degradation. one was essentially anaerobic, while one utilized the cellulose equally well under either condition.

CONCLUSIONS

The studies demonstrate extremely high levels of microbial activity in the salt marshes. However, the variability between different microorganisms indicates that successful management of the marshes might possibly be more effectively accomplished by controlling the microflora than by other methods (i.e. by forcing production of protein instead of CO_2). This strongly suggests the need for further study in this area to determine optimum efficiency of coastal management.

Table 9

Growth On Cellulose

Culture	Conditions	CO_2 [1]	O_2 [1]
Z	Aerobic	101,637	26,322
	Anaerobic	8,838	
S-6	Aerobic	85,434	20,544
	Anaerobic	8,838	
273	Aerobic	81,015	20,544
	Anaerobic	73,650	
S-14	Aerobic	1,473	1,926
	Anaerobic	75,123	

[1] Expressed as μg CO_2 produced or μg O_2 utilized per test in 4 weeks

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PART III

FAUNAL DYNAMICS

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INTRODUCTION

Salt marshes are highly productive ecosystems which constitute extensive coastal features along the Atlantic and Gulf coasts of the United States. Most of our knowledge of the marsh ecosystem has come from studies in the *Spartina alterniflora* marshes of Georgia (see Teal, 1962 for review). Recently Day *et al*. (1973), Nixon and Oviatt (1973), Kraeuter and Wolf (1973) and Subrahmanyam *et al*. (1976) have presented considerable information on the ecology of tidal marshes. Of these only Day *et al*. (1973) and Subrahmanyam *et al*. (1976) investigate salt marsh ecosystems on the Gulf Coast. A few other studies on select marsh organisms of the Gulf are available (Fleeger *et al*., 1979; Kilby, 1955; Menzel, 1971; Reid, 1954; Subrahmanyam and Drake, 1975). This study represents the first attempt to investigate the faunal components (macroepifaunal, macroinfaunal and meiofaunal) of the salt marshes of coastal Alabama and the first investigation of the faunal components of a *Distichlis spicata* marsh.

The purpose of the study was threefold:

1) to determine the composition, abundance and variation of the macro- and meio-faunal components of three natural marshes in coastal Alabama (*Spartina alterniflora*, *Juncus roemerianus* and *Distichlis spicata*) over a two year period

2) to determine the biomass of these various components, and

3) to determine possible relationships between various parameters (salinity, temperature, total organic carbon, sediment texture and plant biomass) and the faunal communities.

MATERIALS AND METHODS

SAMPLE SITE LOCATIONS

Three coastal salt marshes in Alabama were sampled on a monthly basis from February 1977 to December 1978 (See Sec. I Fig. A-2). The *Spartina alterniflora* marsh, located on Dauphin Island was regularly inundated by saline waters; the *Juncus roemerianus* marsh also located on Dauphin Island was flooded on an irregular basis; and the *Distichlis spicata* marsh, located at Point aux Pins west of Bayou La Batre was only infrequently flooded.

BIOLOGICAL PARAMETERS

Macrofauna (infauna and epifauna)

Four replicate samples for macrofauna were taken from each natural marsh on a monthly basis (with the exception of December, 1977 and January, 1978) by removing a 0.10 m^2 plot to a depth of 15 cm. The samples were taken back to the lab and washed through a box screen with 1 mm mesh. All materials remaining on the screen were fixed in 15% formalin, and stained with Rose Bengal (Rose Bengal is a vital stain specific to animal protein). Macrofauna were removed from the plant debris, identified to species and stored in 70% iso-propyl alcohol.

Meiofauna

Three replicate samples for meiofauna were taken from each natural marsh on a monthly basis by removing a 3.5 cm diameter core to a depth of 5 cm. Organisms were removed from the sediment by:

1) sieving the sample through 0.5 mm and 0.063 mm mesh sieves,

2) material remaining on the 0.0063 mm sieve processed through sugar flotation technique of Coull and Sikora (personal communication).

3) pellet from #2 dispersed and stained with rose bengal in iso-propyl alcohol,

4) supernate poured through 0.063 mm sieve, any materials remaining on sieve added to 3 above,

5) sample sorted under 12 x magnification to major taxa. Further identification of some taxa accomplished after initial sorting.

Biomass measurements

Biomass was calculated by multiplying mean weights of ten individuals by the mean abundance of the species. Macrofaunal dry weights were determined by washing individuals of each species in distilled water, drying to constant weight at 110° C, then weighing on an analytical balance with a sensitivity of ± 0.01 mg. Meiofaunal dry weights were determined by rinsing a known number of individuals of the dominant taxa in distilled water, placing them on a small piece of foil, drying to constant weight at 110° C, then weighing on a micro-torsion balance with a sensitivity of ± 0.0002 mg.

Data analysis

Macrofaunal counts were adjusted by a factor of 10 to give numbers m^{-2}; meiofaunal counts were adjusted by a factor of 1.039 to give numbers 10 cm^{-2}. Vertical bars on figs. 1, 3-9 represent one standard error about the $\overline{X}$ from the replicate samples.

Four species diversity indices were calculated for the monthly data. The Shannon-Wiener information function (H') was calculated, using $\log_{10}$, as a composite index including both evenness and richness (Shannon and Weaver, 1949). Pielou's (1969) J' index was calculated, also using $\log_{10}$, as a measure of evenness of distribution of individuals among species. Number of species was used as a richness index.

Fager's (1972) SND index was used as an independent estimate of evenness (J' is biased since it is, in part, dependent upon H').

PHYSICAL PARAMETERS

Temperature and Salinity

Sediment temperature was measured by inserting a field thermometer into the undisturbed sediment to an average depth of 3 cm. At least three replicate measurements were taken during each sampling and the mean determined.

Salinity of the interstitial water was measured with a hand-held temperature compensated refractometer. A core was removed from the sediment of each marsh type and water allowed to collect in the hole. The water was removed with a syringe and placed on the refractometer. Measurements were made in triplicate and the mean determined.

Total oxidizable matter (Organic C)

Total oxidizable matter in the sediment was determined using the Walkley and Black (1934) modification of Schollenberger's (1927) chromic acid oxidation technique in which all oxidizable matter in a sample is oxidized by chromic acid in the presence of excess sulfuric acid. After reaction, the excess chromic acid is back titrated with a ferrous solution. Three replicates from each sample site/month were analyzed and the percent oxidizable matter in the form of carbon determined using: $\%\ C = \frac{V_1 - V_2}{W} \times 0.003 \times 100$

where V_1 = vol. N $K_2\ Cr_2\ 0_7$

V_2 = vol. Fe SO_4

W = weight of soil

(Note 1 ml of N $CR_2\ 0_7$ is equivalent to 3 mg C). The mean value for each marsh/month was calculated from the replicates.

Sediment texture

Due to differences between the marsh sediments, two methods of sediment textural analysis were employed. Samples from the D. spicata marsh, containing large amounts of sand, were dry sieved using a ro-tap. Samples from the J. roemerianus and S. alterniflora marshes, consisting primarily of silts and clays, were analyzed using pipette analysis (Folk, 1974). Three replicates for each marsh/month were analyzed and the mean value determined.

Plant biomass

Data collected by J. Stout.

RESULTS

MACROFAUNA

Representatives of four major phyla were collected from Alabama marshes during the study period (Table I). The most common were the polychaete Nereis succinea, members of the class Oligochaeta, the molluscs Littorina irrorata, Melampus bidentata, Neritina reclivata, Geukensia demissa and Polymesoda carolinana and fiddler crabs of the genus Uca.

Seasonal variation of macrofaunal (taxa) abundance (number m^{-2}) is shown in Fig. 1. Macrofaunal abundance of each of the marshes studied increased significantly in 1978. These increases (S. alterniflora: 391%, J. roemerianus: 1219%, D. spicata: 152%) were due primarily to increases within the class Oligochaeta (620%, 2856% and 206% increase respectively). Over the 24 month period the S. alterniflora marsh shows greatest fluctuations; the D. spicata and J. roemerianus marshes show more predictable seasonal abundance patterns.

Table I. Total annual macrofaunal abundance ($\overline{X}$ m^{-2}) for three coastal Alabama marshes.

	Juncus roemerianus			*Spartina alterniflora*			*Distichlis spicata*		
	1977	1978	GT	1977	1978	GT	1977	1978	GT
Annelida									
F. Capitellidae	0	483	483				45	47	92
Heteromastus filiformis				5	0	5			
F. Nereidae									
Lycastopsis sp.	10	0	10						
Nereis succinea	24	627	651	234	368	602	13	35	48
C. Oligochaetae	91	2599	2690	1026	6363	7389	476	983	1459
Mollusca									
Littorina irrorata		19	19	249	251	500	3	0	3
Melampus bidentata	159	221	380	8	3	11	61	13	74
Neritina reclivata	23	73	96	121	51	172	243	448	691
Geukensia demissa	5	5	10	87	84	171	26	38	64
Polymesoda carolinana		363	363	0	3	3			
Rangia cuneata							10	0	10
Crustacea									
Aramadillum vulgare	3	7	10				3	0	3
Gammarus mucronatus		3	3	20	6	26			
Orchestia grillus	3		3				71	3	74
Sesarma reticulatum	28	41	69	10	0	10			
Uca sp. A	19	110	129	66	93	159	79	50	129
Uca longisignalis				0	55	55			
Uca minax	3	33	36	0	14	14	0	9	9
Uca pugilator				43	13	56			
Uca virens		3	3	0	15	15	0	3	3
Insecta									
O. Coleoptera	7		7				56	0	56
O. Odonta							8	0	8
F. Chironomidae		3	3	3	5	8	3	0	3
Unidentified	3	21	24	0	3	3	3	45	48
Total/year	378	4611	4989	1872	7327	9199	1100	1674	2774

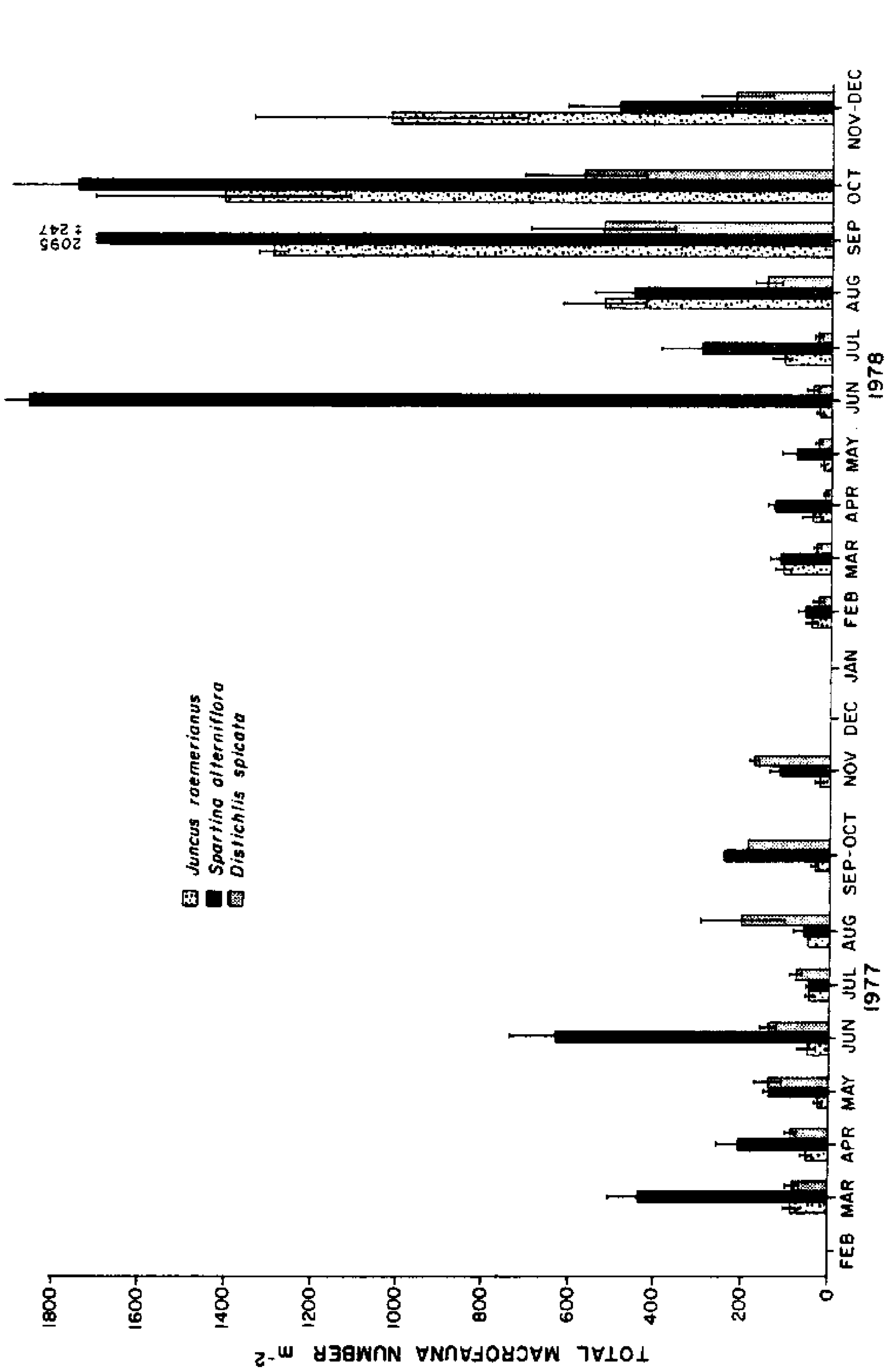

Figure 1. Macrofaunal abundance (# m^{-2}) for three Alabama coastal marshes 1977–1978.

Diversity indices calculated for each of the marshes are a measure of the total community structure for the marsh. Monthly fluctuations in diversity (H') values are evident for all marshes (fig. 2). For the 24 month period (77-78, Table II) the *J. roemerianus* and *D. spicata* marshes showed similar high diversity values, the *S. alterniflora* marsh showed significantly lower values. On a yearly basis (i.e. 1977 and 1978) a significant decrease in macrofaunal diversity values in the *S. alterniflora* marsh and a slight decrease in macrofaunal diversity values in the *D. spicata* marsh are noted. The *J. roemerianus* marsh maintained consistent high values between the two years (Table II).

Spartina alterniflora

The macrofaunal community of this marsh is dominated by members of the class Oligochaeta (80%) and with the polychaete *Nereis succinea* (7%), the molluscs *Littorina irrorata* (5%), *Neritina reclivata* (2%), and *Geukensia demissa* (2%), and the crustacean *Uca* sp. A (2%) make up 98% of the macrofauna encountered (Table III).

Seasonal variation of tha major taxa is shown in Fig. 3. Oligochaeta are the most variable obtaining peaks in abundance in March, June and September-October 1977 and June and September 1978. Decrease abundance is most noticeable in July-August 1977, November 1977 - May 1978. The mollusca show distinct seasonal patterns with peaks in March, June, July and September of both years. Peak crustacean abundance shifted from early spring (March 1977) to early fall (September 1978) with lows during the late spring - summer (exception of July 1978 when a large number of *Uca* spp. were encountered). Polychaete abundance was highest in June and September-October with lows in the spring.

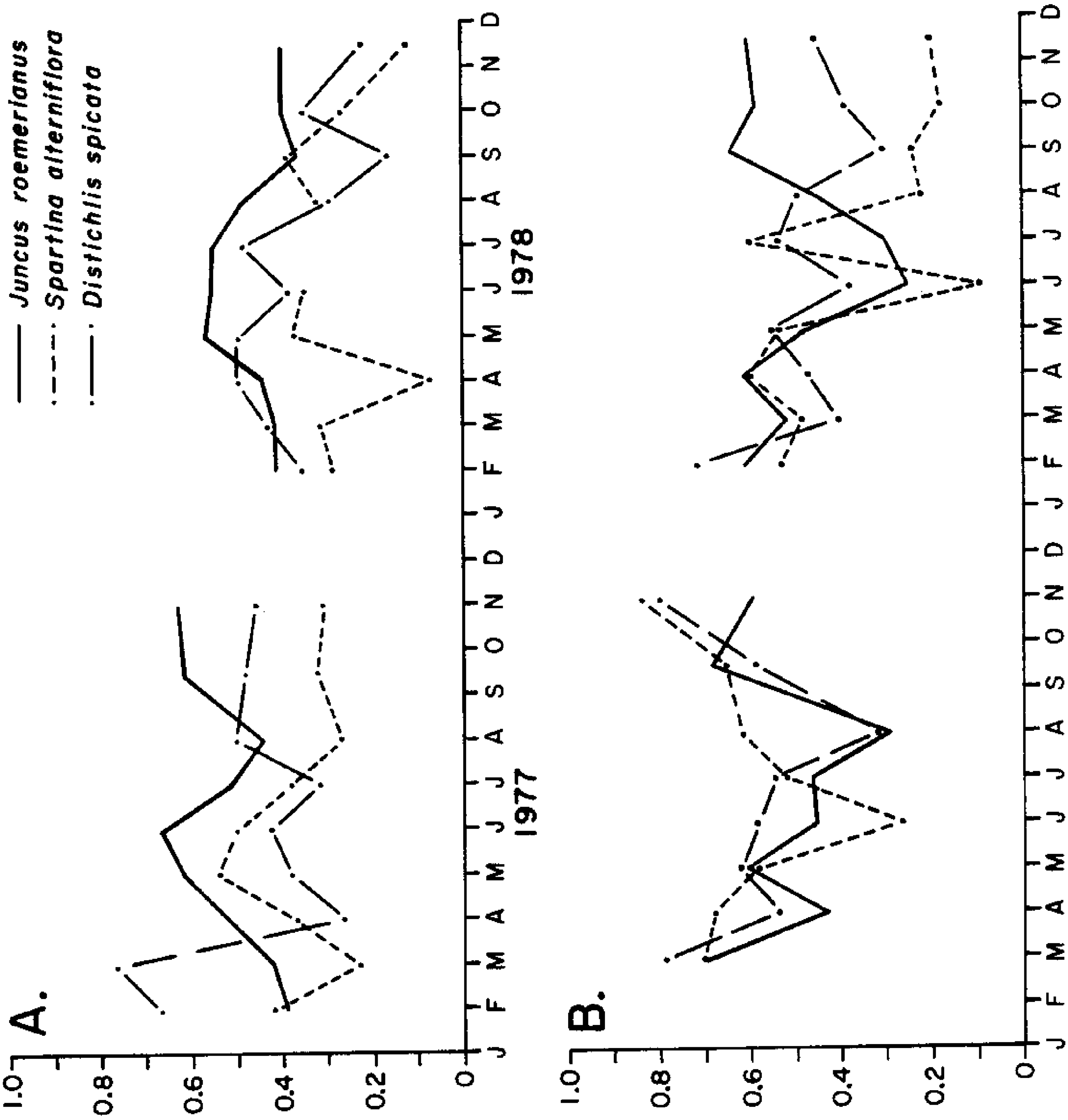

Figure 2a. Monthly H' diversity values for macrofaunal communities of three Alabama coastal marshes 1977-1978.

2b. Monthly H' diversity values for meiofaunal communities of three Alabama coastal marshes 1977-1978.

Table II. Diversity indices for the macrofaunal and meiofaunal communities of three coastal Alabama marshes.

	S. alterniflora			*J. roemerianus*			*D. spicata*		
	1977	1978	77-78	1977	1978	77-78	1977	1978	77-78
Macrofauna									
H'	0.66	0.27	0.37	0.77	0.65	0.69	0.78	0.53	0.66
J'	0.61	0.23	0.30	0.69	0.54	0.54	0.66	0.51	0.54
SDN	0.28	0.16	0.07	0.15	0.05	0.16	0.25	0.17	0.17
# species	13	16	17	12	15	19	15	11	17
Meiofauna									
H'	0.38	0.28	0.31	0.56	0.53	0.55	0.50	0.44	0.50
J'	0.36	0.29	0.29	0.59	0.55	0.55	0.48	0.46	0.48
SDN	0.09	0.07	0.07	0.22	0.18	0.19	0.15	0.15	0.15
# species	11	9	11	9	9	10	11	9	11

Table III. Monthly macrofaunal abundance ($\overline{X}$ m^{-2}) in the *Spartina alterniflora* marsh of coastal Alabama.

	1977								1978									
	M	A	M	J	J	A	S-O	N	F	M	A	M	J	J	A	S	O	N-D
Annelida																		
F. Capitellidae																		
Heteromastus filliformis	5																	
F. Nereidae																		
Lycastopsis sp.																		
Nereis succinea	33	25	28	43		20	60	25	20		5	25	53	17	48	70	100	30
C. Oligochaeta	200	75	73	530		23	100	25	7	33	50	43	1780	160	390	1870	1590	440
Mollusca																		
Littorina irrorata	101	50	3	30	10	10	40	5	27	65	40	3		47	3	50	3	13
Melampus bidentata	3							5								3		
Neritina reclivata	18	38		15	20			30			10		5	13	5	10	5	3
Geukensia demissa	33	3	18		5	3	20	5		13	13		15	3		13	24	3
Polymesoda carolinana																3		
Rangia cuneata																		
Crustacea																		
Aramadillum vulgare																		
Gammarus macronatus	15							5							3		3	
Orchestia grillus																		
Sesarma reticulatum	5							5										
Uca sp. A	18	3		8	5	7	10	15	7	10	5	3		27	3	25	10	3
Uca longisignalis											3		5	7		30	10	
Uca minax												3		3		8		
Uca pugilator		13	20				10				5	5		3				
Uca virens																15		
Insecta																		
O. Coleoptera																		
O. Odonta																		
F. Chironomidae			3														5	
Unidentified													3					
Total/year	431	207	145	626	40	63	240	120	61	121	131	82	1861	280	452	2097	1750	492

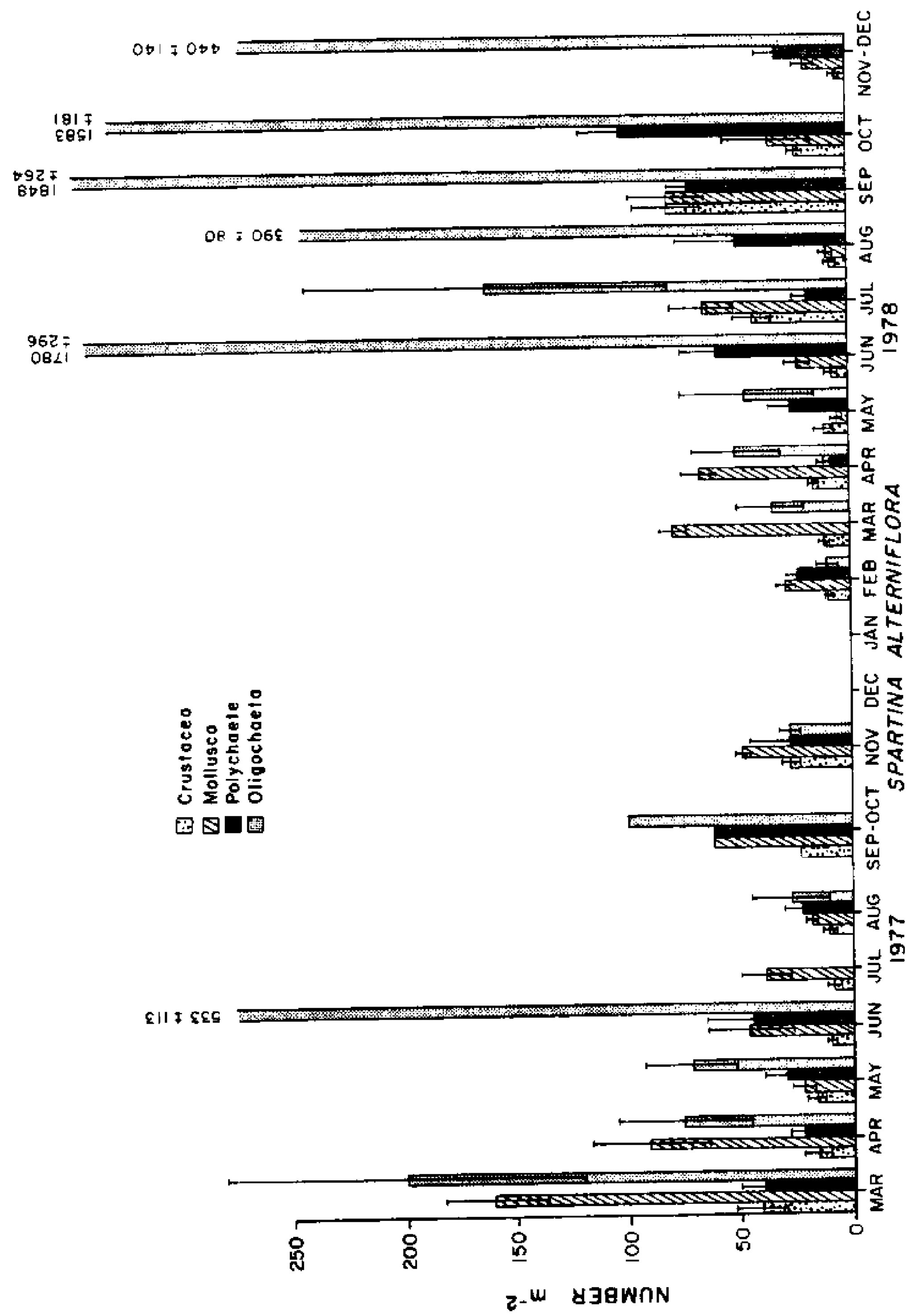

Figure 3. Macrofaunal taxa abundance (# m^{-2}) for the Spartina alterniflora marsh 1977-1978.

Diversity values for the macrofauna decreased significantly in late 1978 due to increase in oligochaete abundance. Prior to that time the values indicated similar trends for the 24 month period with highs in early spring decreasing to lows in June and beginning increases in July (Fig. 2a).

Juncus roemerianus

Members of the class Oligochaeta (54%) dominate the macrofaunal community and with the polychaetes *Nereis succinea* (13%) and unidentified capitellidae (10%), the molluscs *Melampus bidentata* (8%) and *Polymesoda carolinana* (7%), and the crustacean *Uca* sp. A (3%) make up 95% of the community of the *J. roemerianus* marsh (Table IV).

Seasonal variation within this marsh was not significant until August 1978 when increases in all three major taxa occurred (Fig. 4).

Diversity values show annual fluctuations with lows in summer and highs in fall-winter-spring (Fig. 2a). Overall diversity between years in the *J. roemerianus* marsh are similarly high.

Distichlis spicata

The class Oligochaeta is the dominant macrofaunal organism in this marsh (53%). The molluscs *Neritina reclivata* (25%) and *Melampus bidentata* (3%), the crustaceans *Uca* sp. A (5%) and Orchestia grillus (3%), and unidentified polychaetes of the family Capitellidae (3%) contribute significantly to the total (92%). Insect larvae of various types contribute 4% to the total (Table V).

Seasonal fluctuations in the *D. spicata* marsh were due primarily to fluctuations in the oligochaetes and molluscs (Fig. 5). Oligochaeta showed peak abundances in May-June 1977, August-September-October 1977 and

Table IV. Monthly macrofaunal abundance ($\overline{X}\ m^{-2}$) in the _Juncus roemerianus_ marsh of coastal Alabama.

	1977								1978									
	M	A	M	J	J	A	S-O	N	F	M	A	M	J	J	A	S	O	N-D
Annelida																		
F. Capitellidae																143	90	250
Heteromastus filiformis																		
F. Nereidae																		
Lycastopsis sp.		5					5											
Nereis succinea	3	3	3				5	10	17	15	17	5		3	80	165	235	90
C. Oligochaeta	8			33	20	20	10		10	65				3	370	713	908	530
Mollusca																		
Littorina irrorata												5			3	3	8	
Melampus bidentata	40	38	13	10	23	30	5		10	15			20	88	10	53	10	15
Neritina reclivata	10	3	5					5		10		5	7		3	5	23	20
Geukensia demissa								5								5		
Polymesoda carolinana									3	5	7				43	135	85	85
Rangia cuneata																		
Crustacea																		
Aramadillum vulgare			3								7							
Gammarus macronatus																3		
Orchestia	3																	
Sesarma reticulatum	15				3		10				3				3	5	5	25
Uca sp. A	3	5	3		3			5	3		3			20	18	38	28	
Uca longisignalis																		
Uca minax				3												5	13	15
Uca pugilator																		
Uca virens																3		
Insecta																		
O. Coleoptera				7														
O. Odonta																		
F. Chironomidae															3			
Unidentified	3															8	13	
Total/month	85	54	27	53	49	50	35	25	43	110	37	15	27	114	533	1284	1418	1030

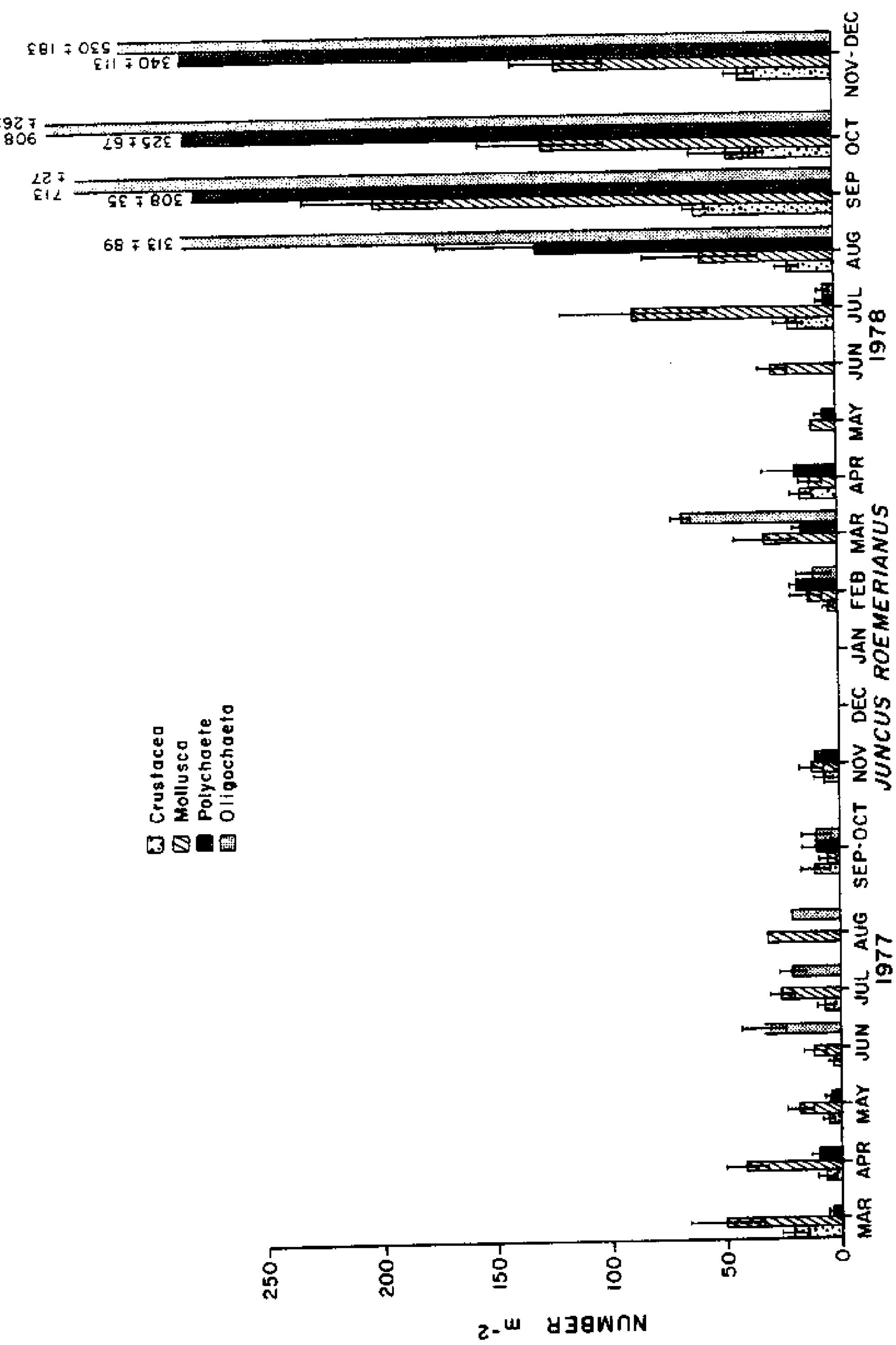

Figure 4. Macrofaunal taxa abundance (# m^{-2}) for the Juncus roemerianus marsh 1977-1978.

Table V. Monthly macrofaunal abundance ($\overline{X}$ m^{-2}) in the Distichlis spicata marsh of coastal Alabama.

	1977								1978									
	M	A	M	J	J	A	S-O	N	F	M	A	M	J	J	A	S	O	N-D
Annelida																		
F. Capitellidae							20	25								27	20	
Heteromastus filiformis																		
F. Nereidae																		
Lycastopsis sp.																		
Nereis succinea				8				5									17	18
C. Oligochaeta	3	3	85	80	20	165	80	40	3	17	5	5			30	390	390	143
Mullusca																		
Littorina irrorata				3														
Melampus bidentata	8	3	10	25	5		10		8					5				
Neritina reclivata	33	48	3	8	38	18	60	35	10	3	3	20	30	10	78	103	133	58
Geukensia demissa	8		3			10		5	3			3	5				17	10
Polymesoda caroliniana																		
Rangia cuneata						5		5										
Crustacea																		
Aramadillum vulgare			3															
Gammarus mucronatus																		
Orchestia grillus	5	8	13	20				25	3									
Sesarma reticulatum																		
Uca sp. A	13	3	8				20	35	5	13		3	3	15	8		3	
Uca longisignalis																		
Uca minax											3						3	3
Uca pugilator																		
Uca virens																3		
Insecta																		
O. Coleoptera	3	20	10	5	13	5												
O. Odonta			5	3														
F. Chironomidae	3																	
Unidentified	3											3	3	3	30	3	3	
Total/month	79	85	140	152	76	203	190	175	32	33	11	34	41	33	146	526	586	232

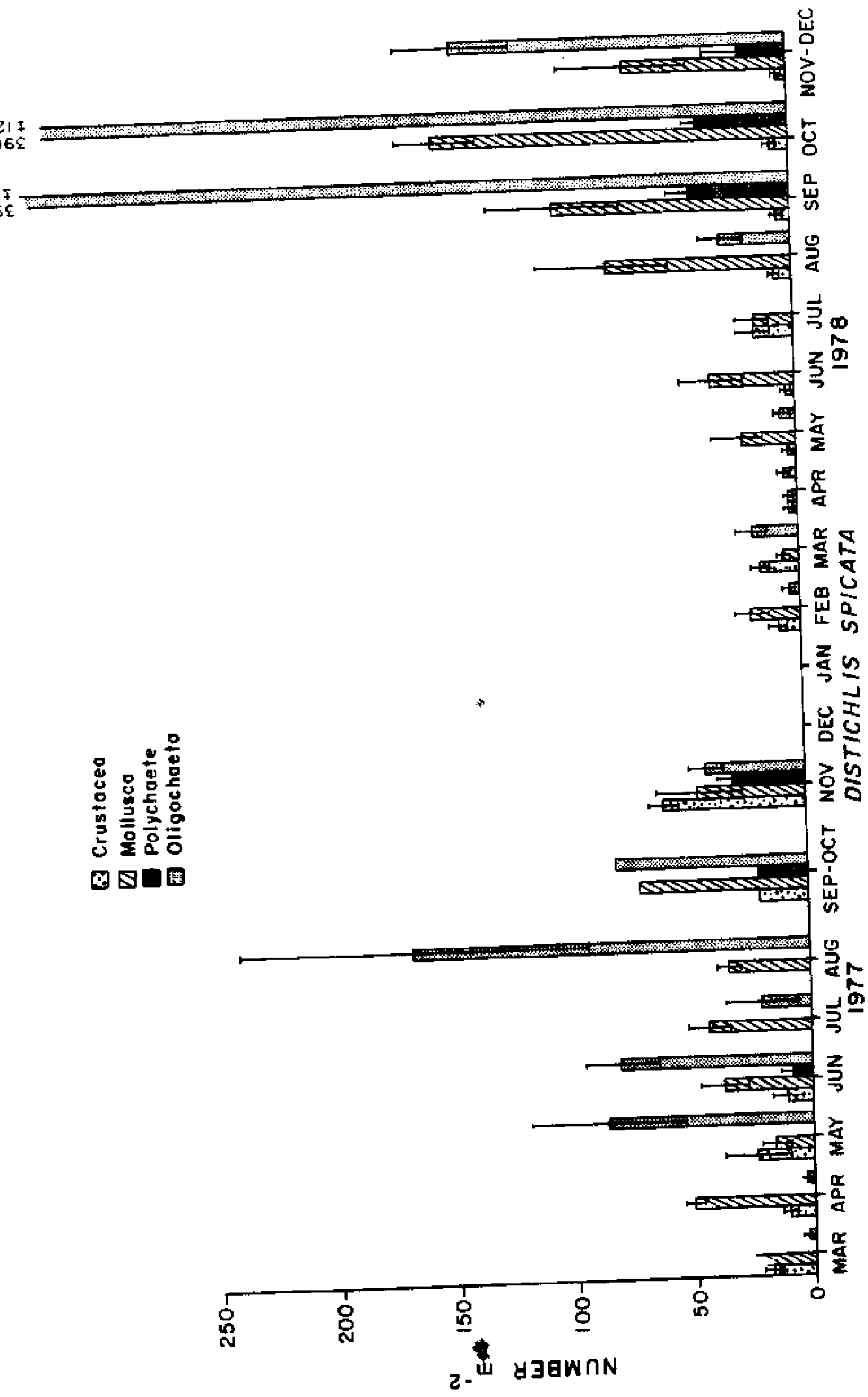

Figure 5. Macrofaunal taxa abundance (# m^{-2}) for the Distichlis spicata marsh 1977-1978.

September-October 1978. Mollusca remained relatively constant until August 1978 when significant increases occurred through October.

There was a slight decrease in diversity between 1977 and 1978 due primarily to increase in Oligochaeta and net emigration of 4 species from the study site. Diversity values for the 24 months, however, remained high (Table II). Monthly fluctuations in H' showed no trends between the two years (Fig. 2a).

MEIOFAUNA

Representatives of eleven meiofaunal taxa were collected from Alabama marshes during the study period (Table VI). The phylum Nematoda comprised greater than 50% of the total meiofauna collected in each marsh during the study period. Harpacticoid copepods and meiofaunal sized oligochaetes were second and third in abundance, respectively.

Seasonal fluctuation of total meiofaunal abundance for the three marshes is shown in Fig. 6. During the 1977 period the D. spicata marsh showed the greatest fluctuations, in 1978 however the S. alterniflora marsh was most variable. The J. roemerianus marsh is most predictable with summer lows and spring and fall highs in abundance.

Diversity indices calculated for meiofaunal components show that diversity remained relatively constant between the 2 years studied (S. alterniflora showed slight decrease). J. roemerianus was most diverse but only slightly greater than D. spicata and S. alterniflora was least diverse (Table II). Monthly fluctuations in H' diversity reflect these yearly values and will be discussed in more detail in what follows.

Spartina alterniflora

The S. alterniflora marsh is dominated by Nematoda (72%), Harpacti-

Table VI. Total annual meiofaunal abundance ($\overline{X}$ 10 cm^{-2}) for three coastal Alabama marshes.

	Juncus roemerianus			*Spartina alterniflora*			*Distichlis spicata*		
	1977	1978	GT	1977	1978	GT	1977	1978	GT
C. Tubellaria	6	11	17	8	4	12	44	3	47
P. Gastrotricha				1	0	1	1	0	1
P. Kinoryncha	10	0	10	3	2	5	2	2	4
P. Nematoda	269	346	615	643	1741	2384	819	348	1167
C. Polychaeta	4	34	38	4	4	8	5	4	9
C. Oligochaeta	56	58	114	10	46	56	68	5	73
C. Aracnida	5	2	7	8	1	9	39	4	43
SC. Ostracoda	0	1	1	2	0	2	35	3	38
SC. Copepoda	147	143	290	356	456	812	234	238	472
P. Insecta	8	3	11	2	1	3	5	0	5
F. Chironomidae	11	4	15	4	3	7	4	32	36
Total/year	516	602	1118	1041	2258	3299	1256	639	1895

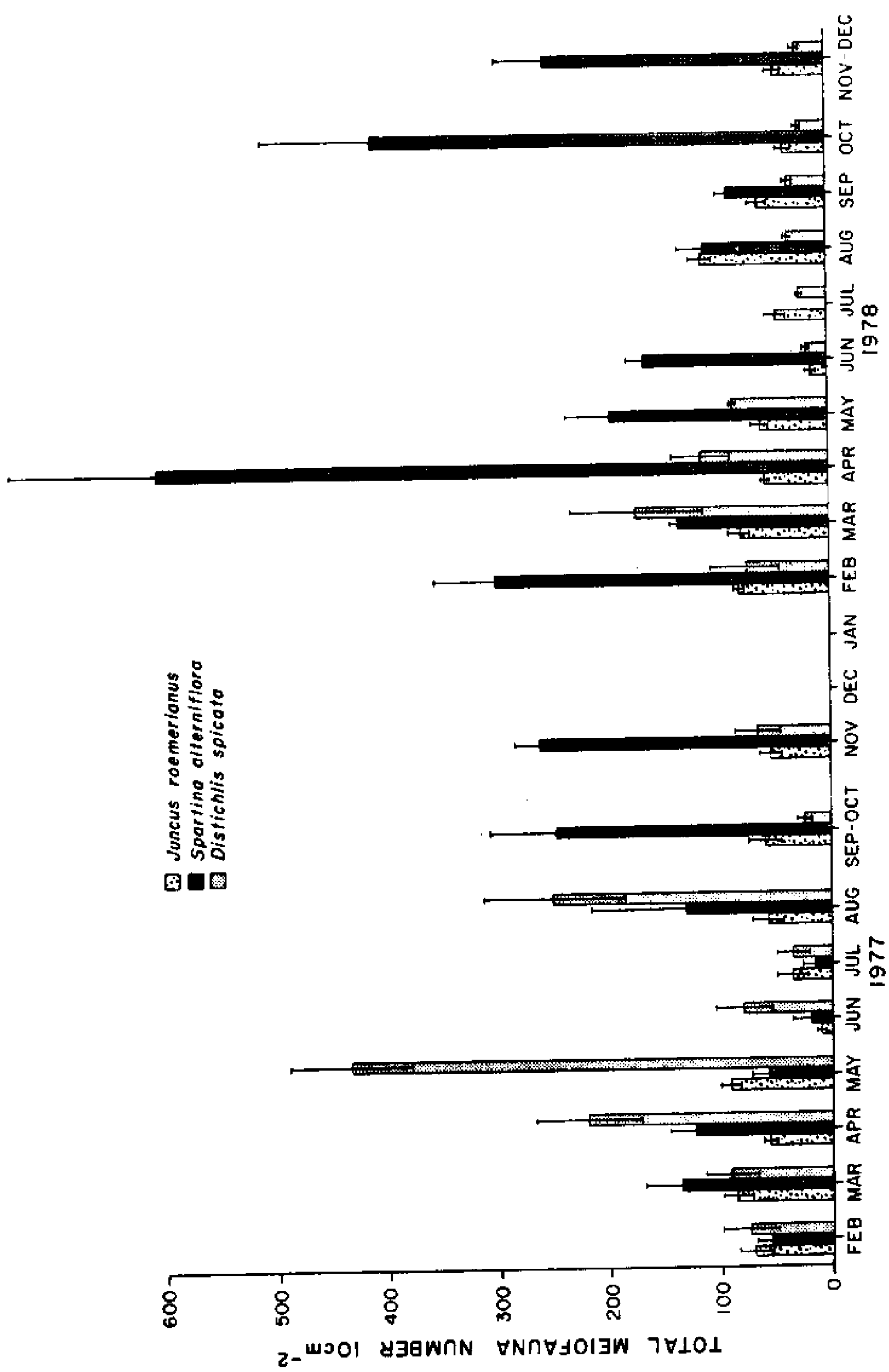

Figure 6. Meiofaunal taxa abundance (# 10 cm^{-2}) for the three Alabama coastal marshes 1977-1978.

coid Copepoda (25%) and Oligochaeta (2%) with a total of eleven groups being represented (Table VII). Seasonal variation of the three dominant taxa is shown in Fig. 7. The nematodes show abundance peaks in spring and fall and lows in summer. Copepod seasonality in 1977 (spring-winter peaks, summer lows) was not evident in 1978 (spring-winter lows, summer-fall peaks). Oligochaeta remained relatively constant (low numbers throughout the 24 months).

Monthly diversity values show trends of decreasing diversity in spring and fall and increasing in summer (Fig. 2b). Overall S. alterniflora meiofauna diversity is low compared to the other marshes (Table II).

Juncus roemerianus

This marsh is dominated by Nematoda (55%), Harpacticoid Copepoda (26%), Oligochaeta (10%), and Polychaeta (3%) with a total of 10 groups represented (Table VII). Little seasonal variation of meiofauna is evident (Fig. 8). Nematoda, Copepoda and Oligochaeta show similar trends with spring and fall peaks and summer lows.

Diversity values indicate the meiofauna to be fairly diverse with little difference between the two years (Table II). On a monthly basis, however, the H' diversity is not predictable over the 24 month period (Fig. 2b).

Distichlis spicata

The meiofauna of the D. spicata marsh is dominated by Nematoda (62%), Harpacticoid Copepoda (25%), Oligochaeta (4%), insect larvae (3%), Tubellaria (2%), Aracnida (2%), Ostracoda (2%) with a total of eleven groups represented (Table IX). Seasonal fluctuation of the three most abundant taxa show trends toward spring and late summer-early fall peaks with summer lows (Fig. 9).

Table VII. Monthly meiofauna abundance ($\bar{X}$ 10 cm^{-2}) in the *Spartina alterniflora* marsh of coastal Alabama.

	1977									1978									
	F	M	A	M	J	J	A	S–O	N	F	M	A	M	J	J	A	S	O	N–D
C. Turbellaria							1	6	1	2		1							1
P. Gastrotricha							1												
P. Kinoryncha	1		1	1						1	1								
P. Nematoda	39	61	79	28	11	8	108	167	142	208	98	587	123	48		70	55	316	236
C. Polychaeta		1		1	1		1				1		1	1		1			
C. Oligochaeta	2	1	1	1	1	1	1	1	1		1	1	8	12		1	9	9	5
C. Aracnida	1	1	1	4			1						1						
SC. Ostracoda	1			1															
SC. Copepoda	11	68	38	21	6	5	18	73	116	88	35	15	60	103		39	24	84	8
P. Insecta		2												1					
F. Chironomidae	1		2		1						1	1	1						
Total/month	56	134	122	57	20	14	131	247	260	299	137	605	194	165		111	88	409	250

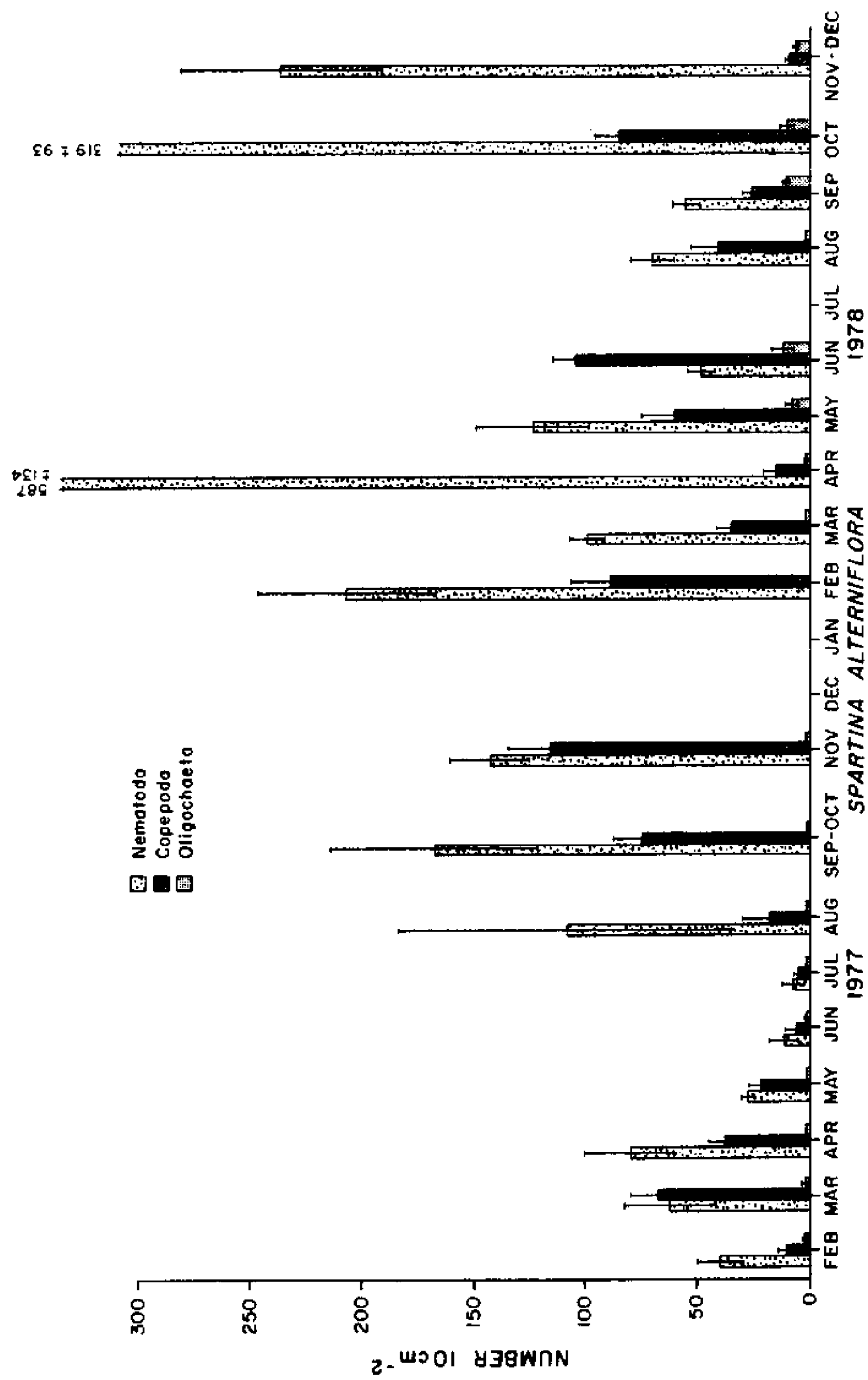

Figure 7. Meiofaunal taxa abundance (# 10 cm^{-2}) for the Spartina alterniflora marsh 1977-1978.

Table VIII. Monthly meiofaunal abundance ($\bar{X}$ 10 cm^{-2}) in the Juncus roemerianus marsh of coastal Alabama.

	1977									1978									
	F	M	A	M	J	J	A	S-O	N	F	M	A	M	J	J	A	S	O	N-D
C. Turbellaria	1						1	1	3	10	1								
P. Gastrotricha																			
P. Kinoryncha		4	2	3					1										
P. Nematoda	54	46	26	44	6	14	32	25	22	44	58	30	23	8	17	66	43	28	29
C. Polychaeta	1		1					1	1		1	1	1	1	17	8	2	2	2
C. Oligochaeta	4	6	3	16	2	4	4	10	7		9	3	6		9	13	4	5	9
C. Aracinida		1	1	1	1				1				1	1					
SC. Ostracoda													1						
SC. Copepoda	11	25	20	22	2	15	16	18	18	27	11	22	27	7	4	25	11	4	5
P. Insecta	1		1	2	1	1	1	1			1	1	1						
F. Chironomidae	1	1	1	1	1	1		4	1		1		1	2					
Total/month	73	83	55	89	13	35	54	60	54	81	82	57	61	19	47	112	60	39	44

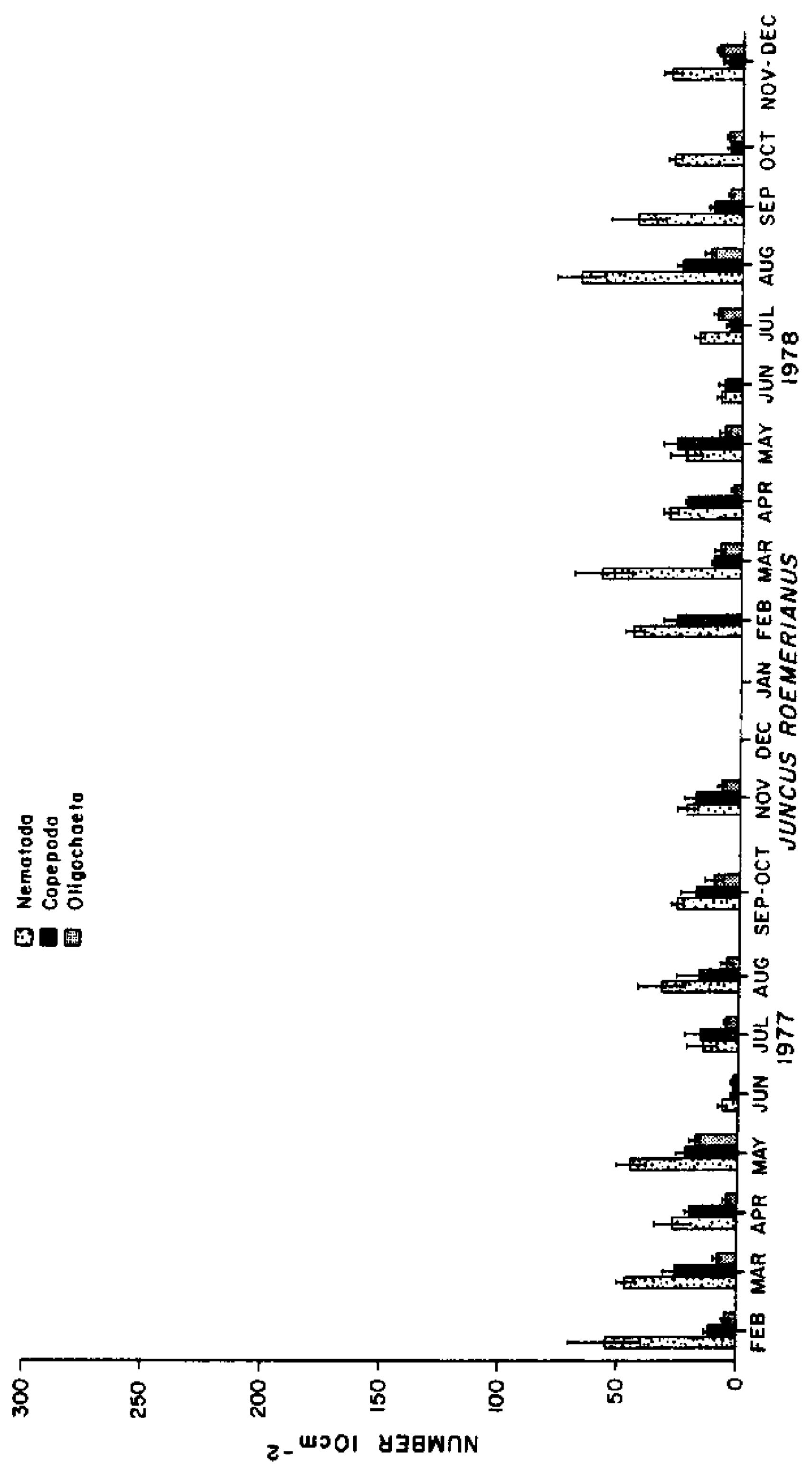

Figure 8. Meiofaunal taxa abundance (# 10 cm^{-2}) for the Juncus roemerianus marsh 1977-1978.

Table IX. Monthly meiofaunal abundance ($\bar{X}$ 10 cm^{-2}) in the <u>Distichlis spicata</u> marsh of coastal Alabama.

	1977									1978									
	F	M	A	M	J	J	A	S-O	N	F	M	A	M	J	J	A	S	O	N-D
C. Turbellaria	26	15		1			1	1		1	1	1							
P. Gastrotricha	1																		
P. Kinoryncha					1				1			1	1						
P. Nematoda	19	26	182	319	47	27	144	16	39	69	103	48	42	9	11	20	29	15	2
C. Polychaeta	1	2						1	1	1	1				1				1
C. Oligochaeta	2	4	4	16	3		37	1	1		1		1		3				
C. Aracnida		17	1	14		1	5		1	1	1	1	1						
SC. Ostracoda	5	2	5	7	1	2	10	2	1		1	1						1	
SC. Copepoda	17	19	25	75	29	2	45	2	20	36	59	51	28	8	12	13	4	8	19
P. Insecta		1	1	1		1			1										
F. Chironomidae	1	2			1					1	10	10	10	1					
Total/month	72	88	218	433	82	33	242	23	65	109	177	113	83	18	27	33	33	24	22

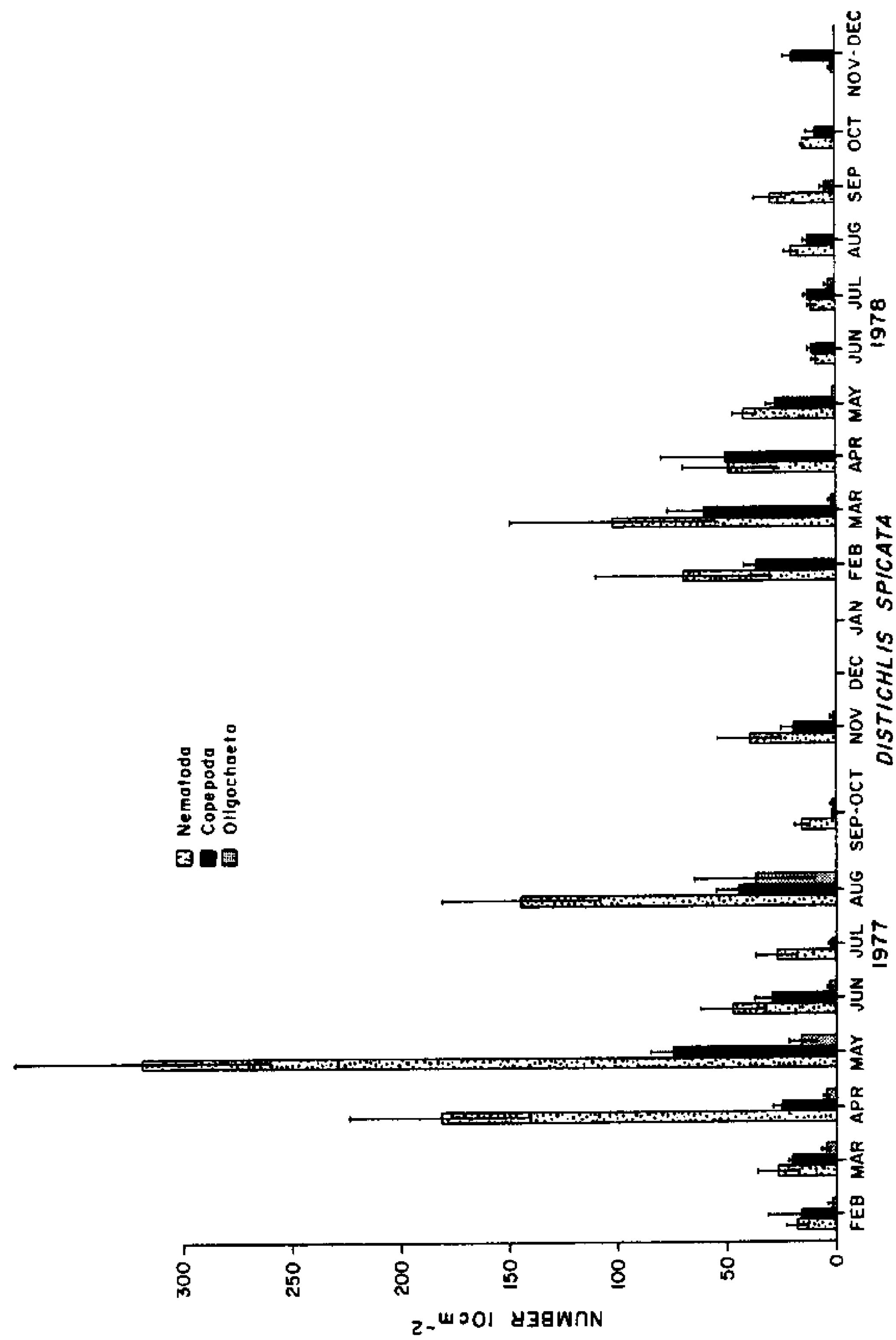

Figure 9. Meiofaunal taxa abundance (# 10 cm^{-2}) for the Distichlis spicata marsh 1977-1978.

Diversity values indicate slight decreases of diversity between years but diversity is still relatively high (Table II). Monthly fluctuations in diversity reveal no pattern of variation (Fig. 2b).

It should be noted that meiofaunal abundance decreased significantly in 1978 (Table VI).

MACROFAUNA-MEIOFAUNA INTERACTIONS

Comparing Figs. 1 and 9 it is evident that meiofauna greatly outnumber the macrofauna per unit area. There is a trend that when macrofauna are low in abundance meiofauna are high and when macrofauna are high meiofauna are low.

BIOMASS

Biomass estimates per unit area are given for the dominant forms in Table X. Biomass of the mollusca are without shells. Ranges are given for many of the organisms due to vast size differences.

PHYSICAL PARAMETERS

Salinity and temperature values are presented in Table XI for the marsh types studied. There were no significant differences in temperature regime between the three marshes for the study period. Significant differences in salinity exist between and within the marshes for the study period. There are however no correlations or trends between or within marshes. These differences are probably due to a combination of tidal factors, precipitation, land runoff and winds. Since these measurements were made on a temporal point basis they will not be considered further.

Total reactive carbon values are markedly different between the three marshes (Fig. 10). *Spartina alterniflora* has the most reactive

Table X. Biomass estimates (g m^{-2}) for abundant organisms in Alabama coastal marshes.

	Juncus roemerianus	*Spartina alterniflora*	*Distichlis spicata*
MACROFAUNA			
Annelida			
F. Capitellidae	1.21 - 2.42	-	0.23 - 0.46
Neris succinea	1.63 - 3.26	1.51 - 3.01	0.12 - 4.75
C. Oligochaeta	13.45 - 672.5	36.95 - 1847.25	7.3 - 364.75
Mollusca			
Littorina irrorata	1.42	37.5	0.23
Melampus bidentata	7.6	0.22	1.48
Neritina reclivata	1.92	3.44	13.82
Geukensia demissa	7.5	128.25	48
Polymesoda carolinana	18.15	-	-
Crustacea			
Gammarus macronatus	-	0.002	-
Orchestia grillus	-	-	.007
Sesarma reticulatum	17.2	2.5	-
Uca sp. A	32.32	39.75	32.32
Uca longisignalis	-	13.75	-
Uca minax	4.5 - 9	1.75 - 3.5	1.13 - 2.25
Uca pugilator	-	14	-
MEIOFAUNA			
Nematoda	0.15 - 0.62	0.6 - 2.38	0.29 - 1.17
Copepoda, Harpacticoida	0.73 - 14.5	2.03 - 40.6	1.18 - 23.6
Oligochaeta	228 - 2,850	112 - 1,400	148 - 1,850
Polychaeta	627 - 950	132 - 200	148.5 - 225
Turbellaria	0.0072	0.0054	0.02
Aracnida	0.04	0.05	0.22
Insecta	650	250	1,025
Ostracoda	0.005	0.009	0.12

Table XI. Temperature and salinity averages for three Alabama coastal marshes March, 1977 - December, 1978.

	Juncus roemerianus		*Spartina alterniflora*		*Distichlis spicata*	
	%	°C	%	°C	%	°C
Mar.	1	14	4	15	5	12
Apr.	2	22	6	23	15	20
May	16	25	18	26	dry	26
June	dry	30	32	32	dry	30
July	dry	33	30	30	dry	30
Aug.	19	27	20	30	10	28
Sept.	NS		NS		NS	
Oct.	22	19	21	19	12	20
Nov.-Dec.	20	12	19	12	10	14
Feb.	0	9	15	12	1	8
Mar.	1	15	2	15	0	16
Apr.	6	21	10	23	13	22
May	5	25	8	28	18	26
June	dry	29	12	28	15	30
July	dry	30	7	33	5	28
Aug.	19	28	19	28	5	28
Sept.	19	21	20	19	19	23
Oct.	17	19	21	20	18	19
Nov.-Dec.	dry	11	21	11	15	11

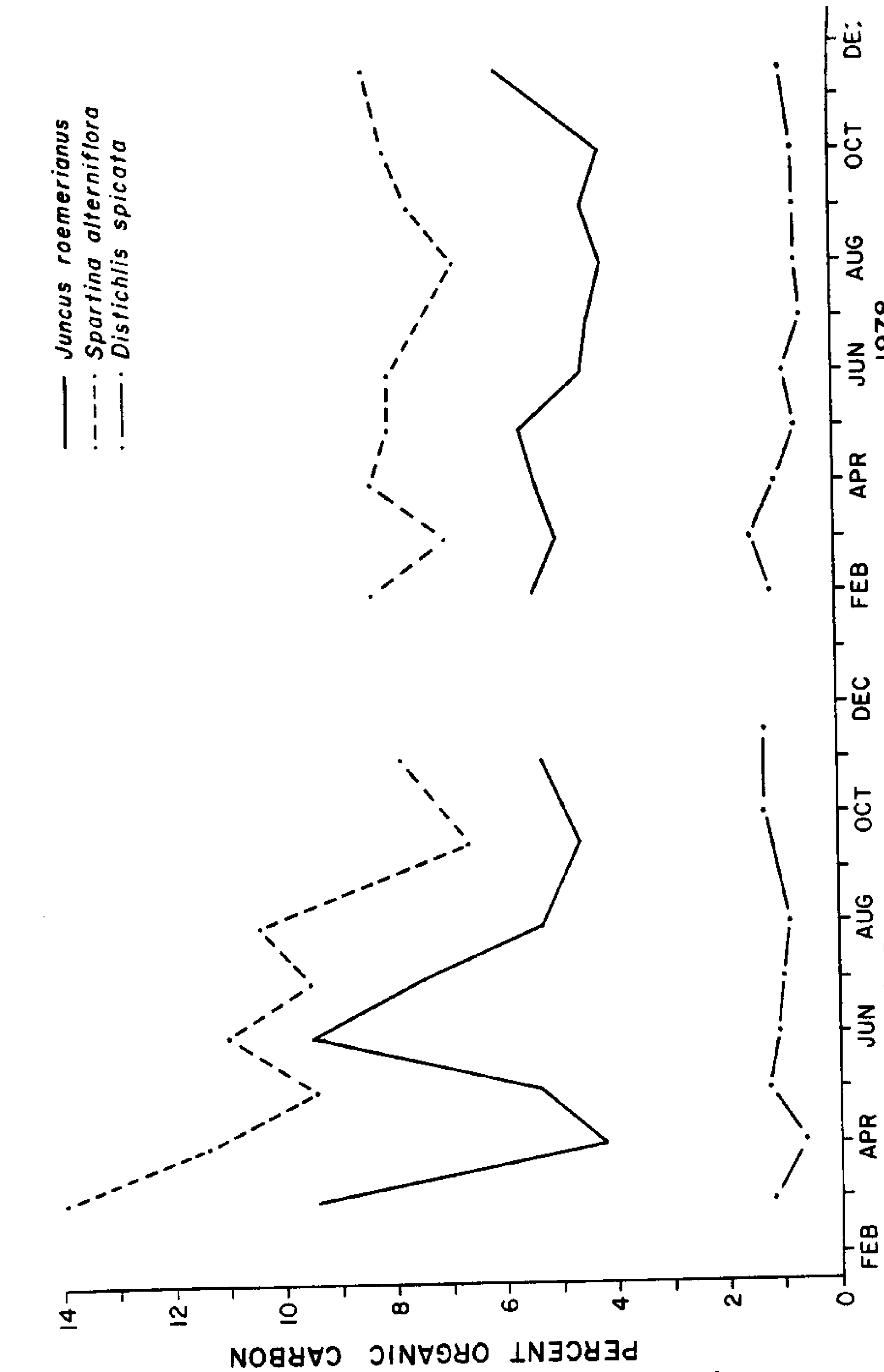

Figure 10. Monthly fluctuations in total reactive carbon for three Alabama coastal marshes 1977-1978.

carbon, Distichlis spicata the lowest. It must be noted, however, that the values obtained in the D. spicata, although low, are constant throughout the year while values from the other two marshes fluctuate widely. Values from the S. alterniflora and J. roemerianus marshes show similar fluctuations. In 1977 both had spring and fall lows and summer highs. In 1978, these fluctuations dropped off drastically with only slight spring-summer highs and fall lows.

Sediment size parameters indicate that the S. alterniflora and the J. roemerianus marshes are markedly similar with high silt-clay content (> 97%). The D. spicata marsh on the other hand contains approximately 15-40 percent by weight sand grains and 85-60 percent silt-clay.

FLORAL-FAUNAL INTERACTIONS

No correlation could be made between the faunal communities and either floral biomass or carbon, hydrogen, nitrogen, phosphorous levels or energy contents of belowground roots and rhizomes at the 0-10 cm level.

DISCUSSION

The marshes investigated in this study have very different faunal communities which are regulated by different mechanisms. In spite of this a few general comments can be made. The fauna found within the marshes represent only a few highly specialized groups. Overall diversity and abundance are low compared to other marine habitats. Abundance of those specialized forms, however, is very high. Within the macrofauna the class Oligochaeta were the dominant organisms. The majority of those found, however, were of terrestrial origin not marine. Within the meiofauna, the Nematoda and Copepoda (Harpacticoida) were dominant, comprising between 80-95% of total abundance. Biomass values were within ranges of those presented for other marsh ecosystems (Day *et al.*, 1973; Nixon and Oviatt, 1973).

Considering the marshes separately and comparatively the *Juncus roemerianus* marsh faunal communities are ecologically the most diverse with eight significant macrofaunal species. Abundance and biomass are "moderate" and undergo moderate seasonal fluctuations. The *Spartina alterniflora* fauna is the least diverse and undergoes the greatest seasonal fluctions in abundance and biomass. The *Distichlis spicata* faunal community is slightly less diverse than the *Juncus* community but experiences only slight seasonal fluctations in abundance and biomass.

The main problem in evaluating these three particular marshes is the highly significant increase within the *Spartina* and *Juncus* community of the terrestrial oligochaetes. This would indicate that the marshes are undergoing succession towards a more terrestrial environment.

In spite of this problem the *Juncus roemerianus* marsh could probably withstand perturbations easier than the other two. The *S. alterniflora* marsh is already perturbed seasonally and the *D. spicata* marsh has such a low abundance of organisms that any perturbation might drastically alter the population.

Within this framework then there is no one criteria which might apply to these marshes in terms of ecological value. Each is important in its own right and is controlled by different processes which led to the formation of the different communities.

Results and discussion on the harpacticoid copepod community have not been included as they are the subject of a masters thesis by J. C. Harp, University of South Alabama. This thesis will be submitted as an addendum to the present report in Summer 1980.

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PART IV

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS AND RECOMMENDATIONS

Though further study is necessary to thoroughly elucidate the various observations of this study the following conclusions and recommendations are made based upon results of this two-year study.

1. The annual net aboveground primary productivity of natural marsh communities in coastal Mississippi and Alabama is within ranges, for the species studied, determined for those species in similar environmental settings. The levels in our studies were, however, on the low end of the range for most species and may indicate a potential for enhanced productivity through management practices along the northern gulf coast.

2. Nitrogen enrichment through application of commercial fertilizers significantly enhances primary productivity of *Spartina alterniflora*, *S. cynosuroides*, and *Juncus roemerianus* in our coastal wetlands. Nitrogen in the form of ammonium is better utilized by marsh plants than nitrogen in the NO_3 form. There appears to be a differential response to fertilization by different growth forms (i.e. short and tall *S. alterniflora*, and high and low marsh *Juncus*). These observations suggest that marsh management by fertilization is not only most applicable to high marsh areas because of suitable hydrology but also very ideal due to the potentially higher biomass production increment of the plant types that grow there. A systematically controlled enrichment experiment among the short, medium and tall ecotypes of *S. alterniflora*, *J. roemerianus* and other marsh vascular species will elucidate more concretely the above observation.

3. Effects of harvesting plant materials vary between species of marsh plants. There appears to be little detrimental effect on productivity and there may even be an increase in biomass production as a result of harvesting. The effects of different harvesting methods and of repeated annual harvest beyond the second year need to be examined before the impact upon the plant communities can be adequately evaluated. In addition, the impact upon other biotic components and system interaction must be determined.

4. Winter fire appears to have a stimulating effect upon the productivity of *Juncus* and *S. cynosuroides* in the immediately subsequent growing season, with greater enhancement exhibited by *Spartina*. The result is temporary for without repeated burning productivity returns to natural levels in the second growing season. Successive burning for two years continues to increase biomass production. Recommendations concerning burning will be made after the results of a third burn have been analysed and the study of effects upon benthic fauna has been completed.

5. The dynamics of decomposition vary between species due to differences in plant tissue composition and physical and biological parameters of the environment of each plant species studied. Alterations of wetlands which result in any of the following may impact the availability and quality of detritus within the system a) Plant species composition; b) Microfloral community; c) Hydrologic regime; d) Meiofaunal community.

6. Though high activity has been demonstrated, the variability between different mocroorganisms indicates that successful management of the marshes may be more effectively accomplished by controlling the microflora than by other methods (i.e. by forcing production of protein instead of CO_2).

7. If enhanced floral productivity through management is possible (as suggested on page IV-1) it is unknown whether this would be reflected in the fauna of the northern Gulf marshes because:

a) knowledge of direct trophic transfer of marsh (floral) biomass to the fauna is undocumented.

b) faunal biomass values are well within ranges presented for other marshes ecosystems even though net aboveground primary productivity levels were on the low range for most species.

c) no correlations could be made between the faunal community and various floral values.

8. If it is possible to manage microflora (i.e. forced production of protein) this may be much more significant in controlling faunal components but these correlations were not part of this study but should be considered in the future.

9. In comparing the physical and faunal communities of three marshes studied on a broad basis the following may be constructed:

	S. alterniflora	J. roemerianus	D. Spicata
Resource Regime	high, highly fluctuating	moderate, moderately fluctuating	low, constant
Macrofauna bimass	highest	moderate	lowest
Diversity	lowest	moderate to high	highest

By controlling the resource regime (total reactive carbon) we might possibly manage the faunal communities. Valentine (1971) predicts that highest diversities will be found in stable, poor resource regimes (small stable population, highly specialized) and in stable, rich resource regimes (mixed population size and specialization). Management through this approach might enrich the *S. alterniflora* and *D. spicata* faunal communities. Again this was not part of the study and should be considered in the future.

10. From the increase in number of oligochaetes of terrestrial origin in the *S. alterniflora* and *J. roemerianus* it appears that these marshes are undergoing succession towards a more terrestrial environment. This is probably due to historic pertubations in each of these areas (i.e. construction of Dauphin Island airport and Government Cut respectively).

11. From "eyeballing" the results of the faunal study it seems that management to produce higher biomass/diversity is possible but much more intense investigation is necessary to determine the hows and whereealls.

the clock on the teletype/paper tape reader side of the interface makes the paper tape reader look to the computer like a very fast teletype, and thus completely compatible. Light emitting diode to phototransistor coupling is used to provide a method of communicating with the computer while keeping it waterproof.

The most important component in this interface is a Universal Asynchronous Receiver-Transmitter integrated circuit (UART). Given a pulse of the send character line, it sends the 8 bits on the computer bus out in a serial fashion on the transmit line at one-sixteenth the clock rate. The receive section of the UART recognizes a start bit from the teletype/papertape reader, changes the subsequent 8 bits of serial data to a parallel form (8 separate lines), and puts the data available line high. A read request signal will put this data onto the computer bus and reset the data available line.

The UART draws considerable power, (60 ma at 10 v and 10 ma at -12v). It is not operational when the submarine is in the water, so power control circuitry is used which supplies power to the UART only when clock pulses are coming in.

The reader relay line allows the computer to request one character at a time from the slow paper tape reader attached to the teletype. When the line is pulled high it sends a single pulse to the reader relay, which should cause the reader to send one character. The reader sends one character most of the time, but occasionally sends two, three, or more when given a single pulse.