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Progress Report of Research: EFFECTS OF ELEVATED CO2 ON CHESAPEAKE BAY WETLANDS. I. Description of the study site.

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REPORT SUMMARY

The Kirkpatrick high marsh consists of a simple assemblage of species well suited for research into the effects of elevated atmospheric CO2 on natural ecosystems. Three plant communities have been selected for the placement of open top chambers for purposes of raising atmospheric CO2 concentrations and measuring net ecosystem CO2 exchange and photosynthesis. These communities contain only three species: Spartina patens (C4), Scirpus olneyi (C3), and Distichlis spicata (C4).

Detailed vegetational studies were carried out in the study area. Forty-five experimental sites were selected within the three communities and characterized for biomass, species composition, stem density and leaf area. Standing live biomass was relatively uniform across communities although the Spartina community had significantly less leaf area than did the Scirpus community. Below ground biomass appeared uniform between these two communities. A vegetation map was constructed for the study area and surrounding high marsh.

Previous ecolgoical and climatological work conducted on Kirkpatrick high marsh was also reviewed. The high marsh is only irregularly flooded and sedimentation and nutrient exchange rates are lower than those of the adjacent low marsh. Measurements of standing live biomass in the study sites agree with previous estimates of biomass.

Plant and soil water relations within the experimental sites were

examined. The *Spartina* community was found to be about 6 cm higher in elevation than the *Scirpus* community with the mixed community being intermediate in elevation. Interstitial water salinity above 15 cm was uniform across communities. Salinity declined with increasing soil depth and at a depth of one meter the *Scirpus* community was about three ppt less saline than the *Spartina* community. These differences were reflected in the predawn plant water potentials where *Scirpus* had on average higher water potentials than did *Spartina*.

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I INTRODUCTION

The projected increase in ambient CO_2 concentration during the next century could have profound effects on plant productivity and therefore on the ecosystem dynamics dependent on production (Oechel and Strain, 1985). Bazzaz et al. (1985) evaluated the uncertainty in predicting effects of increased CO_2 on certain aspects of ecosystem and community level processes. They concluded the current evidence supports the view that: a. biomass will increase, b. community composition will change, c. C4 species will compete less well than C3 species, d. the stimulation of vegetative growth will result in increased reproductive output.

There are several problems with applying these predictions to natural ecosystems. One, is that long-term field tests of the effects of increased CO_2 on vegetation <u>in situ</u> are lacking. This is largely a result of the cost and difficulty of conducting experimental studies in the field. In addition, in generating test atmospheres of a gas whose concentration is very low under normal conditions, it is almost inevitable that the environment of the plant community will be perturbed in ways which may confound our interpretation of the result of our experiments.

These problems are compounded by the fact that there are a wide range of responses of different plant species to CO_2 (Bazzaz et al, 1985). Interpretation of an ecosystem response would be difficult in a plant community having a large number of species given our rudimentary knowledge of plant physiological and ecological responses to elevated CO2 _in situ_.

Tests must therefore be made in the field under conditions which perturb plants as little as possible, and in communities which are simple enough that the results can be interpreted. The experiments we have initiated are being conducted in plant communities consisting of only three monocotyledonous species. Two of these species form monospecific communties and together with the third species, they form a mixed community .

This group of plants is particularly well suited for experiments with elevated CO2. One of the species (_Scirpus olneyii_) is a C3 plant, while the other two (_Spartina patens_ and _Distichlis spicata_) are C4 plants. C3 and C4 species respond in fundamentally different ways to increased CO2. Growth of many C4 plants is not affected by increasing CO2 concentrations but growth of C3 plants increases almost linearly as CO2 increases. Thus, we begin with a relatively simple assemblage of plants which are expected to respond in ways that are interpretable within our current body of knowledge.

We have proposed to examine six aspects of the response of vegetation and ecosystems to elevated CO2. These include responses of photosynthesis, biomass production, elemental composition, and water balance of individual plants as well as relative species composition, and water and carbon balance of the entire plant community. We have begun collecting baseline data for these studies while at the same time working to complete the laboratory and other physical components of our experimental system. Construction of the road and laying of power lines to Kirkpatrick marsh was completed in March 1986. Groundbreaking for the field lab took place in April. The lab and boardwalk were erected simultaneously during April and May. Vegetational surveys for experimental site location were also initiated at this time. Outfitting of the lab and the placement of the first prototype chamber occured in June. Since then the work has shifted steadily away construction of the field site and towards research.

In this report we give details of the plant communities we are studying. First we review previous ecolgical and climatological studies conducted on the Kirkpatrick high marsh. While none of these studies involved CO_2, they nonetheless constitute an important source of background data for our work. Next we present a detailed examination of the vegetation on the high marsh, the selection and location of all experimental sites to be used in this study and some specific characteristics of the vegetation at these sites. Finally, we present preliminary data on plant and soil water relations in the study area. A subsequent report in September will deal with the open top chamber design and testing for purposes of measuring net ecosystem CO_2 exchange and photosynthesis.

II THE KIRKPATRICK HIGH MARSH ECOSYSTEM

The Kirkpatrick high marsh has been studied by several groups in the past although none were concerned with the effects of elevated atmospheric CO_2. We include here a brief summary of the relevant data sets and conclusions reached by their authors. These data come from published and unpublished sources and provide an important data base for comparative purposes. Figure 1 is a map to locate the Rhode River estuary on the Chesapeake Bay and to indicate the location of the study site within the estuary.

Nutrient Dynamics

The Kirkpatrick high marsh, as part of the Muddy Creek watershed and estuary, has been considered within the ecosystem levels studies of Correll and co-workers (Correll et al., 1977; Correll, 1981; Correll et al., 1984; Higman and Correll, 1982; Jordan et al., 1983; Jordan and Correll, 1985). These studies focused on the movement of nitrogen and phosphorus from upland sources through different vegetation types and ultimately into the Rhode River via Muddy Creek. The marshes along Muddy Creek are part of this nutrient flux primarily because they receive and export nutrients during periods of tidal flooding. Nitrogen and phosphorus enter marshes as inorganic forms and are exported as organic species (Jordan et al., 1983). The low marsh is regularly flooded during the tidal cycle and hence has considerable opportunity for nutrient exchange with river waters. The high marsh, however, is only infrequently flooded. This allows limited exchange of nutrients and may in part explain the generally

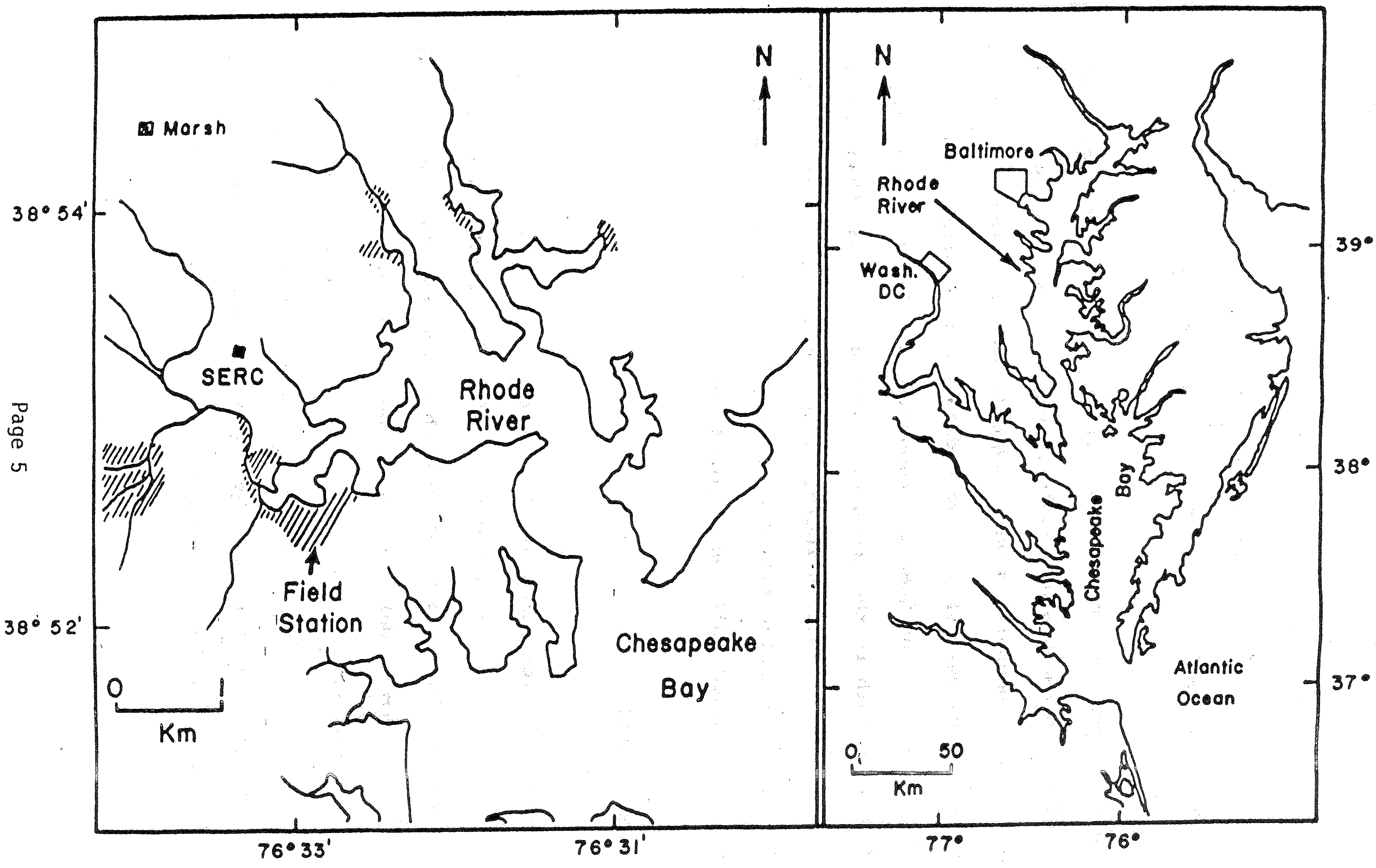


Figure 1. Map locating the study site.

lower productivity of high marshes relative to low marshes. Jordan et al. (1983) estimated a net tidal exchange of -2.8 g m-2 yr-1 N, +0.6 g m-2 yr-1 P, and -57 g m-2 yr-1 C into the high marsh (+ = net import, - = net export). By comparison, the low marsh exchanges +0.9 g m-2 yr-1 N, -0.6 g m-2 yr-1 P, and +11 g m-2 yr-1 C.

Jordan and Correll (1985) analysed interstial water collected from an area in the high marsh approximately 200 m east of the current study site. Two communities were sampled, one dominated by Spartina and one dominated by Scirpus. Their data for interstial N and P are reported in Table 1. The Spartina community was found to have higher levels of N and P both in the inorganic and organic forms than did the Scirpus community. Interestingly, they found no evidence for seasonality in the interstitial nutrient concentrations as might be predicted from seasonal patterns of plant activity.

Climatic Variables

The Kirkpatrick high marsh at the site studied by Jordan and Correll is 47 cm above mean low water. The mean tidal amplitude for the entire year at this site is 31 cm with a mean monthly range from 29 to 32 cm. From tidal records made at Contees wharf, Jordan calculated the frequency of tides sufficient to flood the Kirkpatrick high marsh (Table 2). On average for the year, about 1% of low tides and 20% of high tides will flood the marsh. During September and October, the months with the greatest tidal amplitudes, more than 30% of the high tides flood the high marsh.

Table 1. Interstitial concentrations of nitrogen and phosphorus from two high marsh communities, the _Spartina patens_ zone and the _Scirpus olneyi_ zone (from Jordan and Correll, 1985).

	Spartina	Scirpus
	ppm	
Phosphorus		
PO4 - P	0.16	0.031
DOP - P	0.12	0.031
Nitrogen		
NH4 - N	2.10	0.07
DON - N	1.26	0.84

Table 2. Percent of tides flooding the Kirkpatrick high marsh, 1970-1979 (from T. Jordan, unpublished data).

Month	% of Low Tides	% of High Tides
January	0.5	9.9
February	0.6	9.7
March	1.0	15.0
April	0.2	13.7
May	0.4	21.7
June	0.4	23.7
July	0.2	20.5
August	0.4	21.1
September	1.2	35.0
October	2.6	30.8
November	1.9	26.4
December	1.4	11.9
All Months	0.9	19.8

Seasonal weather records are available for the study site from a meteorological station ca. 1 km north of Kirkpatrick marsh at the main laboratory of the Smithsonian Environmental Reseach Center. Figure 2A shows mean monthly precipitation and figure 2B shows mean monthly daytime and nighttime temperatures for the period 1969-1979. Rhode River salinity levels have also been monitored at Contees wharf but, for reasons discussed later, these correlate poorly with high marsh interstial water salinities.

The high marsh traps sediment from upland and tidal sources. These sediments contribute nutrients and add to the accumulation of peat characteristic of these marshes. Whigham (unpublished) has calculated sedimentation rates on the high marsh using dyed sand plots. In the Spartina zone he found an accumulation of 1.5 mm sediment yr-1 and in the Scirpus/Iva zone 4.2 mm sediment yr-1. Nearby areas of low marsh accumulated between 4.9 and 6.4 mm sediment yr-1.

Vegetation Processes

The dynamics of litter decomposition on the Kirkpatrick high marsh have also been studied. Whigham (unpublished) estimated turnover rates of surface litter in the Spartina zone at 0.76 yr from biomass and productivity data and 4.43 yr from litter bag experiments. An analysis of nitrogen and carbon contents from plant material recovered from litter bags showed that Spartina litter is a relatively poor substrate for microbial colonization and degradation (Fig. 3).

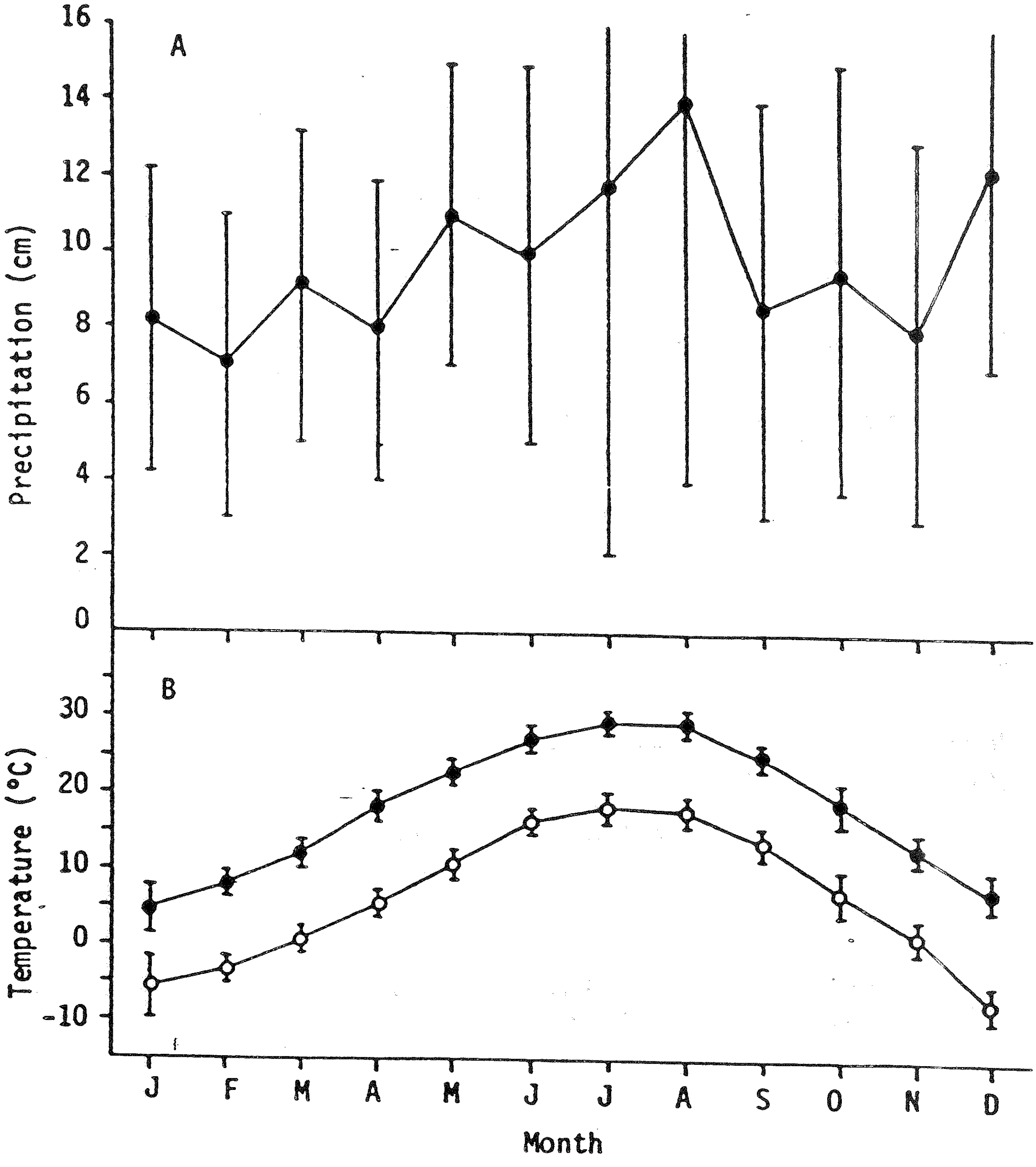


Figure 2. Precipitation and temperature data for the Kirkpatrick high marsh, 1969-1979. A) Mean monthly precipitation. B) Mean monthly daytime (closed circles) and nighttime (open circles) temperatures. Vertical bars indicate standard deviation. After Higman and Correll (1982).

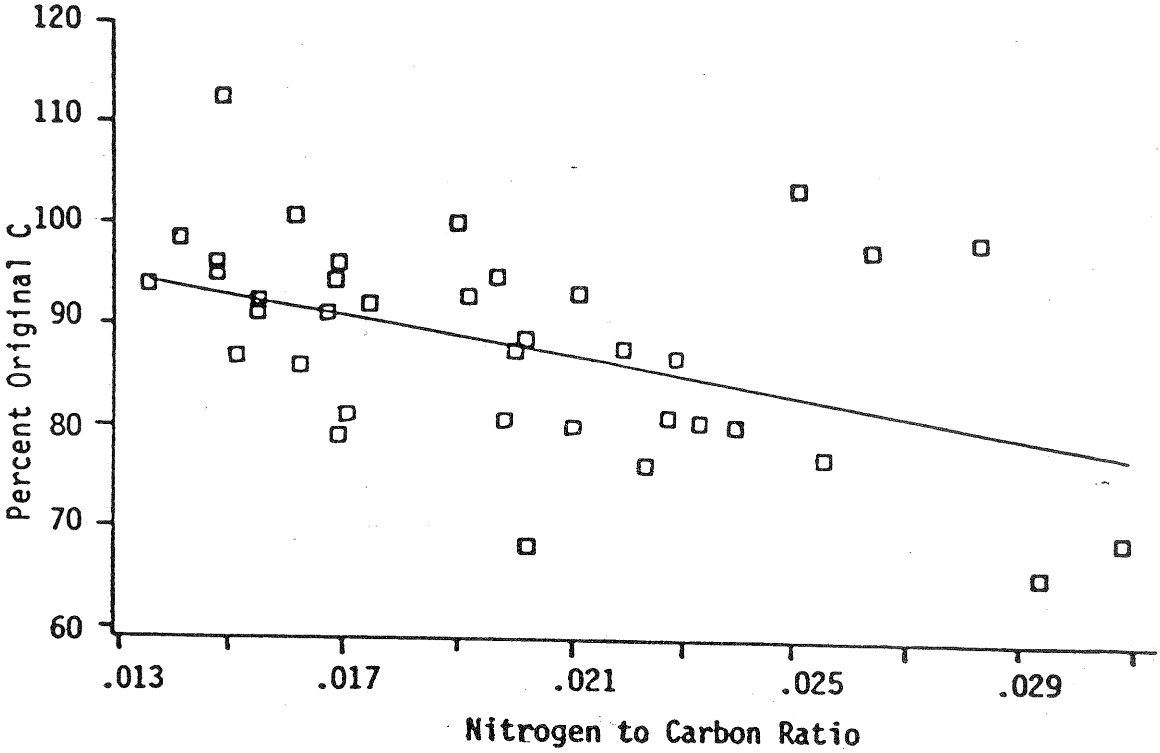


Figure 3. Change in percent original carbon with nitrogen to carbon ratio of Spartina patens litter. From D. Whigham (unpublished).

Nitrogen to carbon ratio was initially rather low and increased slowly with a decline in percent original carbon.

Productivity of the Kirkpatrick high marsh has been measured by a number of workers. The most complete data set was that of Drake (1976) for the years 1973 and 1974. Drake sampled living biomass in a <u>Spartina</u> community and in a mixed <u>Spartina</u>, <u>Distichlis</u>, <u>Scirpus</u> community at frequent intervals between April and December. He found a peak standing biomass in the <u>Spartina</u> community of approximately 600 g m-2 (Fig. 4A) and in the mixed community of approximately 400 g m-2 (Fig. 4B). The <u>Spartina</u> community appeared to reach peak biomass about three weeks later than the mixed community, in mid September versus late August.

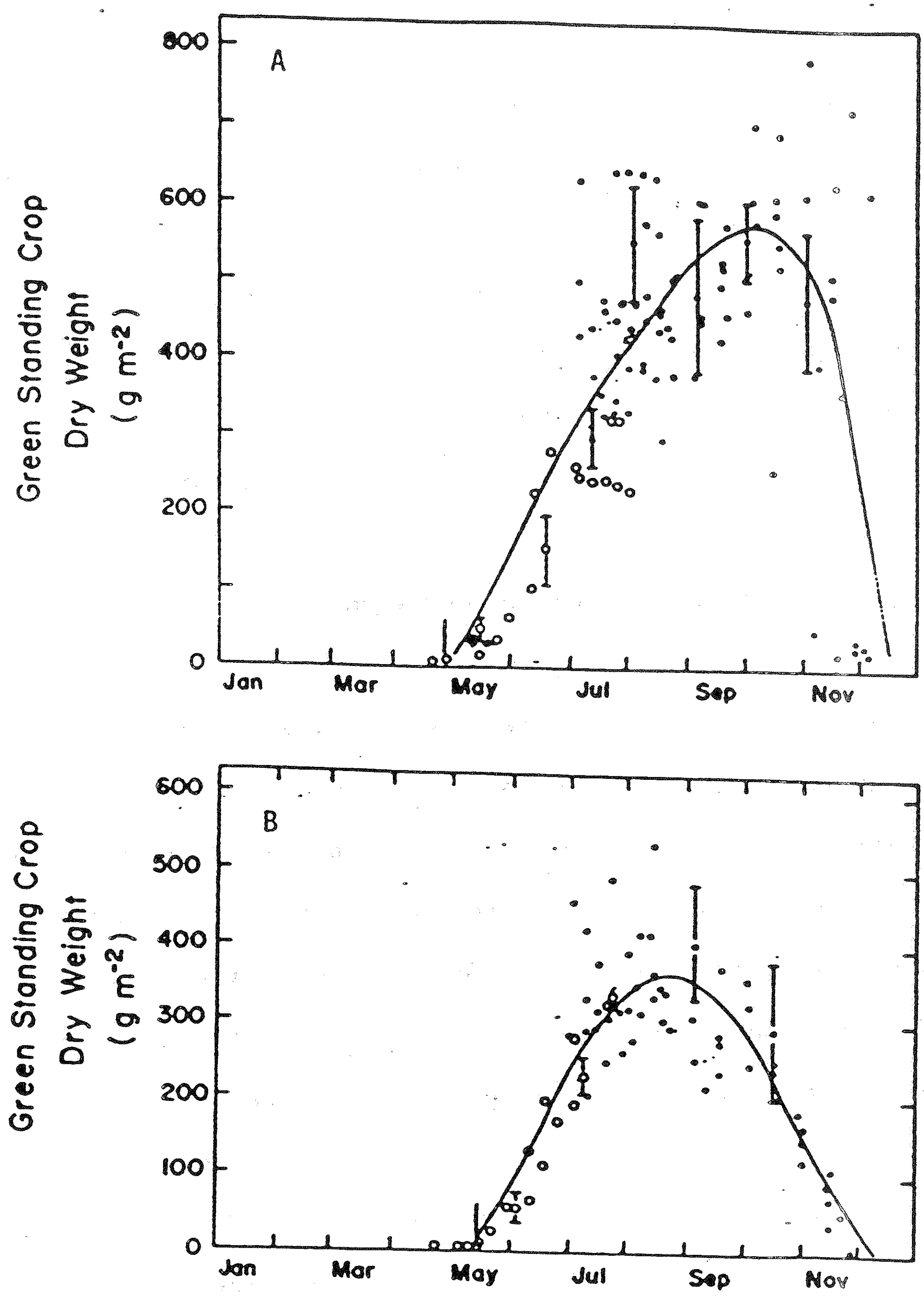


Figure 4. Standing live biomass in two high marsh communities. A) Spartina community. B) Mixed species community. Open circles = 1973 harvest, closed circles = 1974 harvest. Vertical bars indicate standard deviation. After Drake (1976).

III DESCRIPTION OF EXPERIMENTAL SITES

An understanding of the distribution and growth characteristics of the plant species present in the experimental area is of fundamental importance to our study of the effects of elevated CO_2 on the Kirkpatrick high marsh. In this chapter we present the results of our survey of the high marsh in general and the experimental sites in specific. These data represent the first points of a series that will eventually provide a dynamic picture of the salt marsh ecosystem.

Vegetation Map of Kirkpatrick High Marsh

The vegetation of the study area was initially mapped by analysis of an aerial photograph of the marsh. Because the definition of this photograph was not high enough for a detailed mapping of the communities, and because changes in the vegetation may have occurred since the photograph was taken in 1984, the vegetation was surveyed in the field. This was done by establishing a 10 x 10 meter grid over the entire study area. The exact position of the community boundaries, as well as the location of the boardwalk and the 45 experimental sites, was then mapped within each 10 x 10 meter square. Figure 5 shows the map of the Kirkpatrick high marsh obtained from this analysis.

The three communities included in this study are: Spartina (C4), Scirpus (C3), and mixed Spartina, Scirpus, Distichlis (C3/C4). The C4 community forms a continuous stand along the south border of the boardwalk, the C3 community occurs as two connected stands bissected

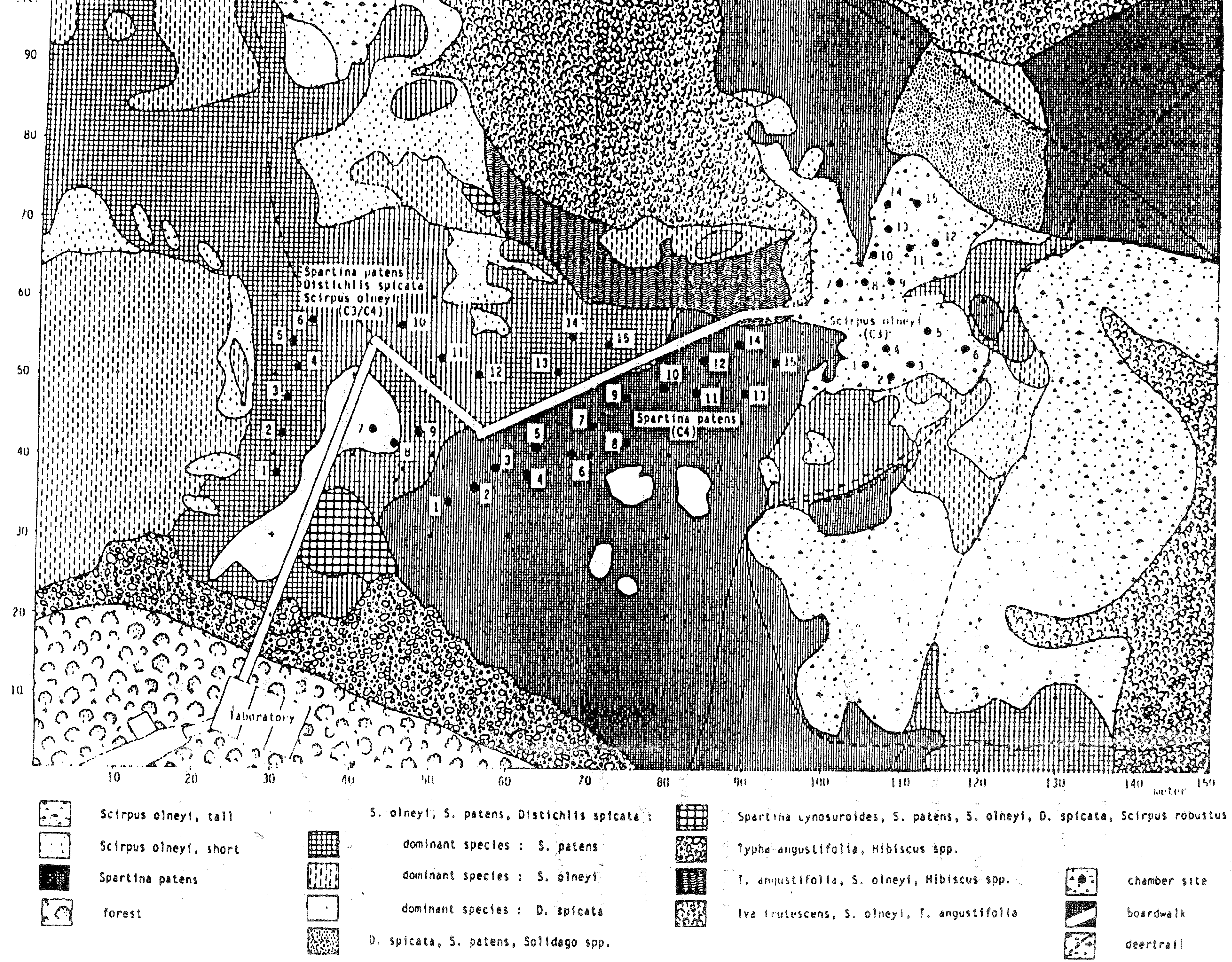


Figure 5. Vegetation map of the study area

by the boardwalk, and the mixed community forms stands along three sides of the boardwalk (Fig. 5). In the mixed community, three associations have been arbitrarily distinguished, each association characterized by a different dominant species. The Scirpus stands outside the study area are subdivided into areas of tall and short growth forms. Figure 5 also includes the other plant communities present in the high marsh, the boardwalk, laboratory, and position of the 15 experimental sites in each of the three communities.

Selection of Experimental Sites

The area available for the location of experimental sites was initially defined by the position of the boardwalk. This area extended approximately 10 m into each community on either side of the boardwalk. A 1.5 m border adjacent to the boardwalk and a 2 m border from the edge of each community was considered unavailable for site placement.

Experimental sites were not located randomly within the available area. Two prior considerations influenced site location. First, it was desireable to minimize the possibility of contamination of air in control sites by air from treated chambers. This was done by establishing a minimum distance for site separation, thereby preventing sites from being located directly next to one another. Second, within the mixed community we sought to minimize the between site variation in Scirpus stem densities.

Minimum distance for site separation was calculated by estimating the total area available within each community (ie. area accessible from the boardwalk minus borders) and then calculating the number of sites that could be located in that area given different between site distances. Site separation of 2.5 m was found to allow 20 sites to be placed in the smallest community (the C3 community), so this distance was taken to be the <u>minimum</u> distance allowable between any two sites.

In order to obtain data on the variation in number of <u>Scirpus</u> stems among experimental sites in the mixed community, transects were run between 5/6/86 and 5/19/86. Results showed a range in densities at that time from 0 to 262 stems m-2. Regions along these transects showing extreme values in stem densities were excluded from consideration for site location. Thus, the actual area of mixed community available for site placement was smaller than the total accessible area.

Location of experimental sites in each community was then made randomly along arbitrarily established transect lines at intervals of 2.5 m or greater where available area permitted.

<u>Description of Experimental Sites</u>

Each site was assayed for species composition, stem density, standing live biomass and standing live leaf area. In each community destructive harvests were made outside of, but in close proximity to, the experimental sites. From these harvests relationships were established between stem density, dry weight, and leaf area for each species. This allowed biomass and leaf area <u>within</u> the experimental sites to be estimated non-destructively. It was a primary concern of ours throughout this study to disturb the experimental sites as little as possible.

Stem densities for *Spartina* and *Distichlis* were estimated by subsampling five 100 cm^2 quadrats within each site. Stem density for a site is the mean of these five quadrats. Leaf area and biomass were then estimated from 100 cm^2 off site destructive harvests. Leaf area was measured with a LI-COR LI-3100 leaf area meter. The single surface values recorded by the leaf area meter were multiplied by two giving total surface area.

All *Scirpus* stems within each site were counted. For *Scirpus*, photosythetic surface area was estimated from off-site destructive harvests by measuring stem length (L) and stem width at the top (W_t) and bottom (W_b) of the stem. *Scirpus* has a regular three sided stem so that $Area = 1.5L(W_t + W_b)$. Stem heights and densities were measured in 0.25 m^2 quadrats near the experimental sites and these data were used to relate measured *Scirpus* stem densities within sites to leaf area and biomass.

Treatments were assigned to experimental sites after the methods of Hurlbert (1983). Sites were first 'blocked' in groups of three within each community. Each of the three treatments was then assigned randomly to one of the three sites within a block. Treatments were: chambers with elevated CO_2 (E), chambers with ambient CO_2 (A), and unchambered controls (C).

Considered together, the fifteen experimental sites within each community provide a detailed picture of each of the three plant communities for a single point in time (Fig. 6). Standing live biomass is not significantly different among communities, being between 300 and 400 g m-2 dry weight, but stem density and leaf area do differ significantly among all three communities. Scirpus has the lowest stem density of 400 stems m-2 while Spartina has more than 4200 stems m-2. The mixed community is similar to the C4 community with 3600 stems m-2. Total leaf area exhibits the opposite trend with Scirpus having 4.5 m2 m-2 green tissue and Spartina having 1.2 m2 m-2. The mixed community is intermediate with 2.6 m2 m-2. In the mixed community, C4 species make up 94% and 85% of the stems and dry weight respectively but contribute only 69% to the total leaf area.

Differences betweeen species in leaf orientation may help to explain the differences in leaf area vs. dry weight accumulation. Area of leaf surface for photosynthesis in Scirpus is vertical which means that although total surface area for interception of light is high, the light interception per unit area is low. Spartina and Distichlis have more horizontal leaves and higher per unit area light interception. Turitzin and Drake (1982) showed that the leaf orientation in these plant communities has a large impact on the net community carbon assimilation rate.

Stem density, leaf area, and dry weight data for individual sites are presented in Tables 3-5. Variation is lowest in the pure C3 and C4 communities. Scirpus stem density ranged from 337 to 617 stems m-2 in pure stands (Table 3) and from 90 to 330 in the mixed community

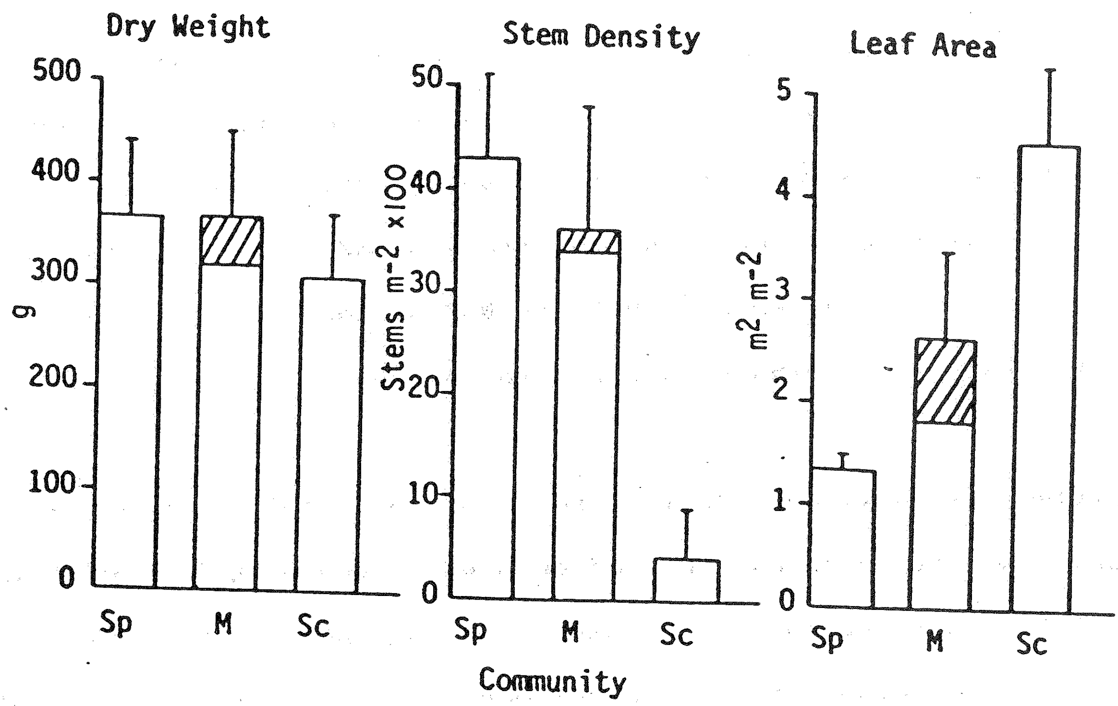


Figure 6. Dry weight, stem density, and leaf area in the experimental sites. Sp = Spartina community, M = mixed community, Sc = Scirpus community. Shaded area indicates fraction of the mixed community represented by Scirpus. Vertical bars indicate standard deviation.

(Table 3). Spartina ranged from 2,960 to 6,180 stems m-2 in pure stands (Table 4) and from 0 to 5,460 in the mixed community (Table 5). Where Spartina is absent or present in low numbers in the mixed community, Distichlis predominates, while the reverse is also true. The leaf area and dry weight data show similar patterns of variation.

Within the mixed community, Scirpus has far fewer stems m-2 per site than either Spartina or Distichlis. This imbalance is not so extreme when considering leaf area or dry weight. Scirpus often has equal or greater leaf area than the C4 species (Table 5). Nonetheless, Scirpus is measureably smaller in the mixed community than in pure stands. At comparable stem densities, mixed community Scirpus has about 1/3 less leaf area and biomass than pure stand Scirpus (eg. Table 3, site 11 vs. Table 5, site 12). This does not appear to be the case for Spartina where leaf areas tend to be greater at comparable stem densities in the mixed community vs. pure stands although dry weights are virtually identical.

These data describe the vegetational composition of each site during the latter half of June 1986. Sequential analyses of this type will enable us to monitor changes in species composition and above ground growth through time as they are affected by our experimental treatments. They will also allow us to interpret canopy gas exchange measurements on a leaf area or biomass basis.

Table 3. Vegetational characteristics of the *Scirpus olneyi* (C3) community. Mean (s.d.), n = 5. E = elevated CO_2 treatment, A = ambient CO_2 treatment, C = unchambered control.

Treatment	Site #	Stem Density m-2 (x100)	Leaf Area m2 m-2		Dry Weight g m-2	
E	1	4.83	5.18	(0.26)	358	(21.7)
	6	5.16	5.54	(0.27)	382	(23.2)
	7	3.77	4.04	(0.20)	279	(17.0)
	10	3.79	4.07	(0.20)	281	(17.1)
	14	4.12	4.42	(0.22)	305	(18.5)
A	2	3.46	3.71	(0.18)	256	(15.6)
	4	3.81	4.09	(0.20)	282	(17.1)
	8	3.68	3.95	(0.19)	273	(16.6)
	12	4.92	5.28	(0.26)	365	(22.1)
	15	4.67	5.01	(0.25)	346	(21.0)
C	3	6.17	6.62	(0.33)	457	(27.8)
	5	4.23	4.54	(0.22)	313	(19.0)
	9	3.75	4.02	(0.20)	278	(16.9)
	11	3.37	3.62	(0.18)	250	(15.2)
	13	3.86	4.14	(0.20)	286	(17.4)

Table 4. Vegetational characteristics of the *Spartina patens* (C4) community. Mean (s.d.), n = 5. E = elevated CO_2 treatment, A = ambient CO_2 treatment, C = unchambered control.

Treatment	Site #	Stem Density m-2 (x100)		Leaf Area m2 m-2		Dry Weight g m-2	
E	1	34.2	(12.81)	1.04	(0.39)	294	(110.2)
	4	38.6	(6.80)	1.17	(2.21)	332	(58.5)
	8	37.4	(10.95)	1.13	(0.33)	322	(94.2)
	10	42.0	(9.03)	1.27	(0.27)	361	(77.7)
	14	41.8	(6.61)	1.27	(0.20)	359	(56.8)
A	2	29.6	(7.16)	0.90	(0.21)	255	(61.6)
	5	61.8	(14.62)	1.87	(0.44)	531	(125.7)
	9	44.2	(9.88)	1.34	(0.30)	380	(85.0)
	11	45.6	(17.69)	1.38	(0.27)	392	(152.1)
	13	40.2	(5.26)	1.22	(0.16)	346	(45.2)
C	3	42.0	(6.44)	1.27	(0.19)	361	(55.4)
	6	43.4	(16.40)	1.32	(0.49)	373	(141.0)
	7	48.6	(14.79)	1.47	(0.44)	418	(127.2)
	12	36.4	(5.86)	1.11	(0.17)	313	(50.4)
	15	58.6	(8.65)	1.78	(0.26)	504	(74.4)

Table 5. Vegetational characteristics of the mixed community. Mean (s.d.), n = 5. S = *Scirpus*, P = *S. patens*, D = *Distichlis*. E = elevated CO_2 treatment, A = ambient CO_2 treatment, C = unchambered control.

Treatment	Site #	Sp.	Stem Density m-2 (x100)		Leaf Area m2 m-2		Dry Weight g m-2	
E	1	S	2.7		1.09	(0.14)	72	(9.3)
		P	25.8	(9.65)	1.19	(0.44)	219	(82.0)
		D	17.0	(6.44)	1.93	(0.73)	190	(72.1)
	4	S	2.4		0.94	(0.12)	62	(8.0)
		P	23.6	(15.60)	1.09	(0.72)	201	(132.6)
		D	6.2	(2.86)	0.71	(0.32)	69	(32.0)
	8	S	3.0		1.20	(0.15)	79	(10.2)
		P	0		0		0	
		D	12.0	(14.27)	1.01	(1.27)	139	(165.5
	11	S	1.0		0.42	(0.05)	27	(3.5)
		P	54.6	(43.03)	4.42	(1.12)	502	(395.5)
		D	0		0		0	
	13	S	1.7		0.68	(0.09)	45	(5.8)
		P	11.0	(7.00)	0.29	(0.18)	101	(64.4)
		D	8.2	(3.35)	0.73	(0.29)	95	(38.9)
A	2	S	2.5		1.01	(0.13)	66	(8.6)
		P	30.6	(14.72)	1.42	(0.64)	260	(125.1)
		D	15.2	(4.55)	1.73	(0.51)	170	(51.0)
	6	S	1.8		0.72	(0.09)	47	(6.2)
		P	43.6	(19.55)	2.02	(0.90)	371	(166.2)
		D	6.2	(2.49)	0.70	(0.28)	69	(27.9)
	9	S	0.9		0.36	(0.05)	24	(3.1)
		P	21.8	(5.17)	0.56	(0.13)	164	(38.8)
		D	15.2	(7.66)	1.35	(0.68)	176	(88.9)
	12	S	3.3		1.32	(0.17)	87	(11.2)
		P	9.4	(5.32)	0.24	(0.13)	86	(48.9)
		D	17.0	(9.97)	1.51	(0.89)	197	(115.7
	15	S	1.6		0.64	(0.08)	42	(5.4)
		P	20.2	(6.61)	0.53	(0.17)	186	(60.8)
		D	2.4	(2.30)	0.21	(0.20)	28	(26.7)
C	3	S	2.4		0.98	(0.12)	64	(8.3)
		P	35.0	(28.71)	1.62	(1.33)	298	(244)
		D	8.2	(7.66)	0.93	(0.87)	92	(85.8)
	5	S	1.7		0.68	(0.09)	45	(5.8)
		P	34.0	(28.97)	1.57	(1.34)	289	(246.2)
		D	3.0	(2.65)	0.34	(0.30)	34	(29.7)
	7	S	2.0		0.80	(0.10)	52	(6.8)
		P	0		0		0	
		D	22.6	(7.47)	2.01	(0.66)	262	(86.7)
	10	S	2.2		0.87	(0.11)	57	(7.4)
		P	24.8	(12.11)	0.65	(0.31)	228	(111.4)
		D	2.8	(2.59)	0.25	(0.23)	32	(30.0)
	14	S	1.3		0.52	(0.07)	34	(4.4)
		P	35.4	(17.60)	0.92	(0.46)	326	(161.9)

Preliminary data on below ground biomass for the _Spartina_ and _Scirpus_ communities are presented in Table 6. Peat cores (5 cm X 20 cm) were taken from each community away from the experimental sites. Cores were cut into 5 cm sections, washed free of inorganic material, dried and weighed. No effort was made to separate living and dead material although qualitative examination of the peat indicated the great majority of the biomass to be living roots and rhizomes. These data indicate roughly equal amounts of below ground biomass in the two communities, each being over 30 times what is present above ground. From this small sample it appears, however, that the carbon is distributed differently below ground. Relatively more biomass is present at 15-20 cm in the _Spartina_ community than in the _Scirpus_ community.

Table 6. Below ground biomass in the _Spartina_ and _Scirpus_ communities. Mean of two 5 cm X 20 cm cores.

Depth cm	_Spartina_ g m-2	%	_Scirpus_ g m-2	%
0-15	9213	75.2	10288	90.6
15-20	3046	24.8	1070	9.4
Total	12259	100	11358	100

IV WATER RELATIONS

Elevation

In a salt marsh, salinity and anoxia of the soil are two important stress factors regulating the growth of the salt marsh species. Salinity and anoxia are dependent on the frequency of flooding with saline water and on the water table in the soil. Flooded areas frequently have a soil salinity which is about equal to the salinity of the water with which it is flooded, while the salinity of less frequently flooded parts of the marsh may deviate significantly from the salinity of the flood water because of evaporation of water from the marsh, concentrating the salt in the soil, or because of precipitation, lowering the salinity of the soil. The water level in the soil determines the anoxia, which in turn influences the chemical properties of the soil. Both the frequency of flooding and the water level in the soil depend on the elevation of the marsh. It is therefore important to know whether there are differences in elevation between the different communities.

The elevation of the soil has been measured for all 45 experimental sites relative to an arbitrary watermark on the boardwalk. The resulting data are shown in fig. 7. These results show that the elevation of the Scirpus sites is on the average 6 cm. lower than the Spartina sites, with the elevation of the mixed community intermediate between the two monospecific communities. Further measurement within the study area may provide information on whether soil elevation is a factor influencing the distribution of plant

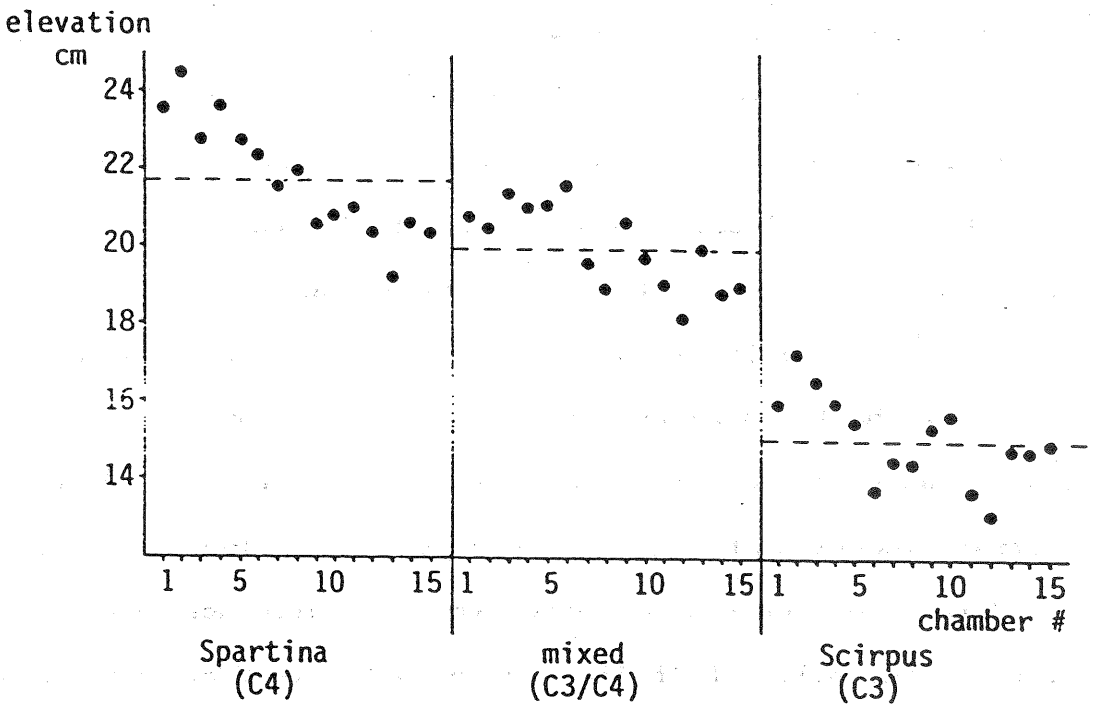


Figure 7. Elevation of the experimental sites. Each point represents a single experimental site within each community.

communities in the salt marsh. The water table will be continuously recorded at one point in the marsh, which, combined with the elevation data, will provide information on the frequency and duration of flooding and the height of the water table in the three communities.

Salinity

Because of the effects of drainage, elevation, tidal amplitude, frequency of flooding, precipitation, and evaporation, salinity in the soil of the salt marsh can differ from place to place, from time to time, and can also vary with the depth in the soil. Soil salinity influences the rate at which plants take up water. Since deep rooting plants may be able to tap a relatively fresh water supply and thereby avoid extreme salt stress, it is neccessary to measure the salinity at different depths in the soil, and to know the rooting depth of the three species. For measuring the salinity in the soil in the different communities, several sets of wells have been placed in each community. A set of wells consists of four pipes (2cm ID), inserted in the marsh to depths of 15, 30, 50 and 100 cm. Six sets of wells have been placed in each community, within the experimental sites intended for destructive sampling. The salinity of the water in the wells is equal to the salinity of the soil layer into which the bottom of the pipe is inserted. The water in the wells is sampled with a tube, and the salinity is measured with either a refractometer or an osmometer.

Initial results are summarized in fig. 8. These data clearly show that the salinity in the soil decreases with increasing depth. At a depth of 15 cm the salinity measured was about 15 ppt in all three communities. The salinity at 100 cm is highest in the *Spartina* stand and lowest in the Scirpus community. These results are complicated by an apparent division of the *Scirpus* community into two parts; an area with a low soil salinity in the wells west of the boardwalk (site 1, 2 and 3) and another area with high soil salinity east of the boardwalk (site 7, 8 and 9). A more extensive survey of the soil salinity within the Scirpus community may provide information on the extent of this division. Since the deeper soil levels can be a source for relatively fresh water for deep rooting species, the rooting depth of the three test species will be compared by examining soil cores taken from the three communities.

Plant Water Potential

The water potential of the three species was measured at several times during a 24 hour cycle with the aid of a pressure bomb. The results of these measurements are shown in fig. 9. The water potential of all species drops rapidly after dawn, reaches a minimum around noon, and increases again during the evening and night. The highest values were recorded just before dawn. The minimum water potential around noon, -24 to -31 bars, did not seem to differ between the three species. At dawn and in the late evening the water potential of *Scirpus* was higher than that of the two C4 species and the lowest values were recorded for *Spartina*. The water potential of *Spartina* tends to be higher in the mixed community than in the pure *Spartina* stand. These water potentials are inversely correlated with the rooting depth of these species and the salinity on the soil: water potential is highest in the *Scirpus* community which has the highest

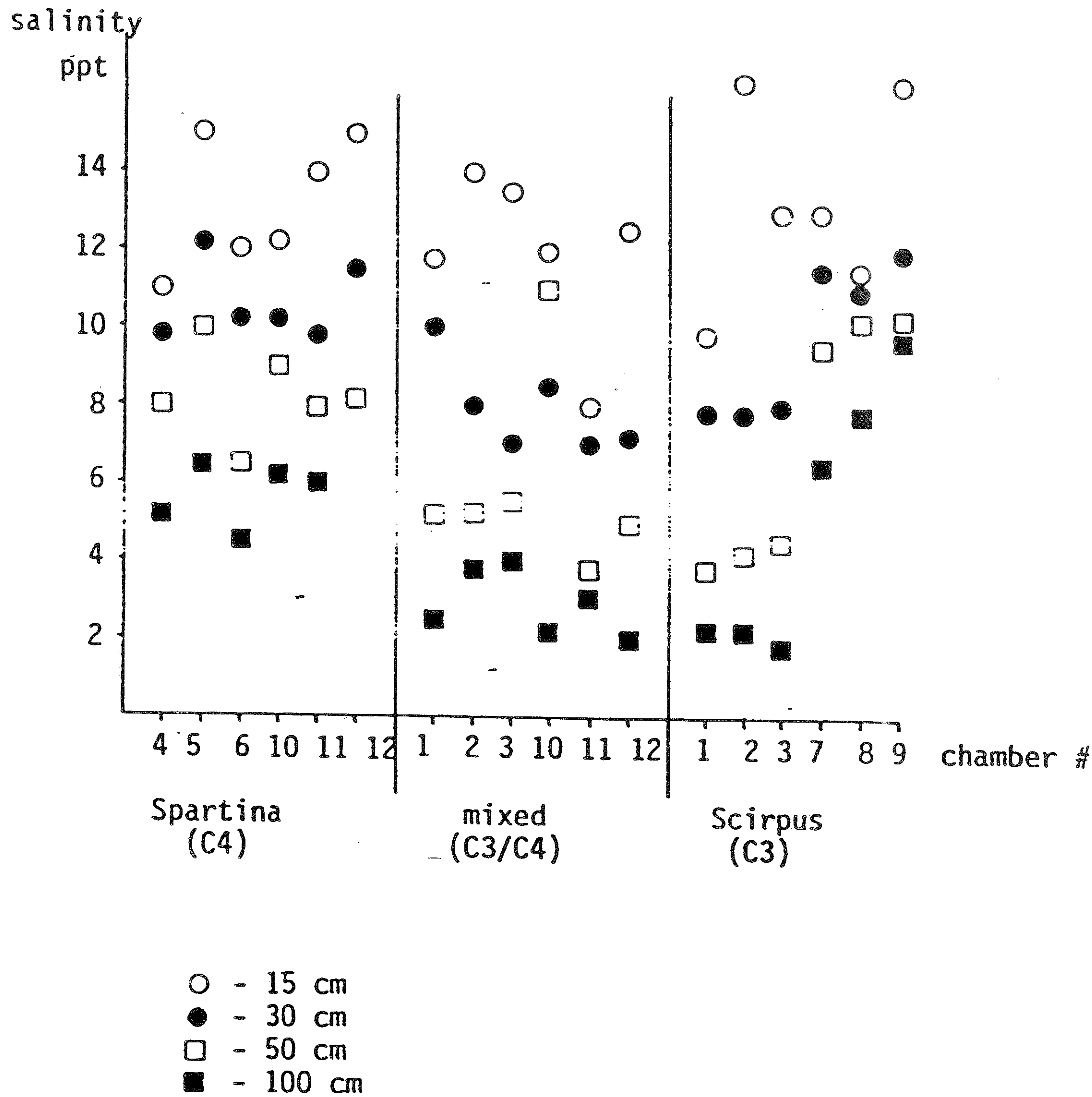
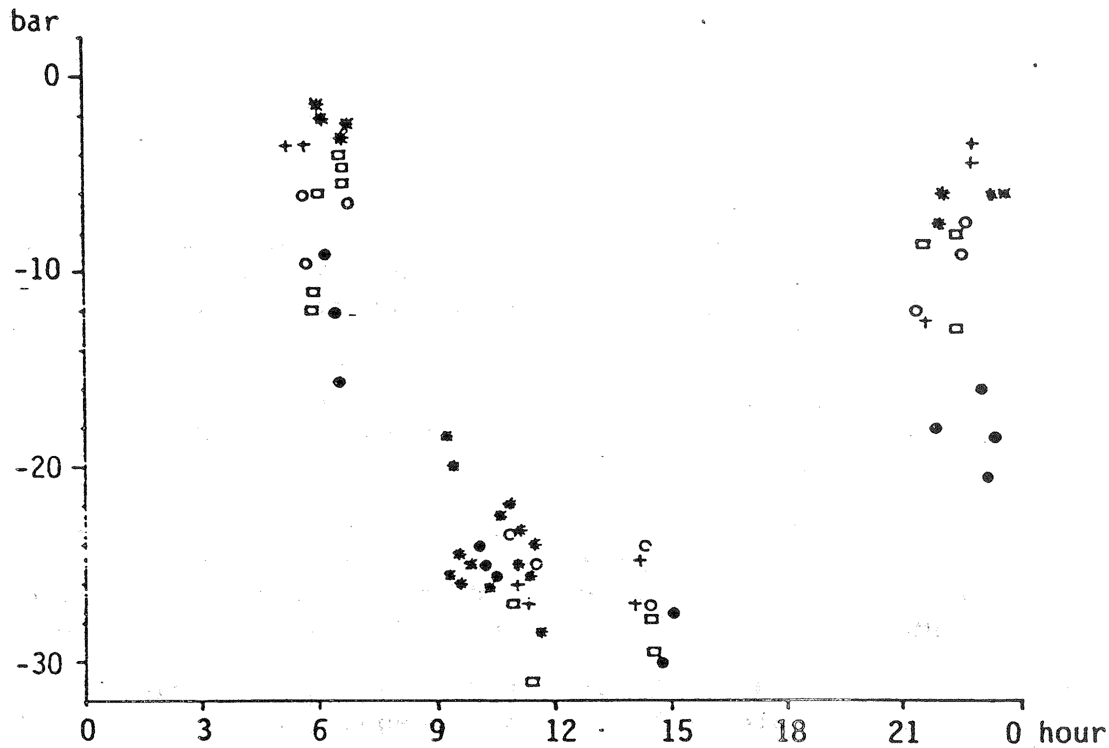


Figure 8. Interstitial water salinity of the experimental sites. A total of six sites per community were sampled at four different depths.

soil water potential and is presumed to have the deepest roots (DeJong and Drake, 1981).



* - Scirpus olneyi in pure stand
\+ - Scirpus olneyi in mixed community
• - Spartina patens in pure stand
o - Spartina-patens in mixed community
□ - Distichlis spicata in mixed community

Figure 9. Diurnal changes in plant water potentials. Measurements were made over the course of a single day.

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