SOME ASPECTS OF THE ECOLOGY AND MANAGEMENT OF *CHENOPODIUM RUBRUM* L. IN THE DELTA MARSH, MANITOBA

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Marilyn Ruth Rayner

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ABSTRACT

Chenopodium rubrum is an annual mud flat colonizer, primarily of inland marshes, characteristic of hydrarch successions at Delta. The species most commonly associated with C. rubrum in the three Delta habitats studied (Marsh Shores, Wet Meadows and Ridge Marshes) were Phragmites communis, Lycopus asper, Atriplex patula and Aster brachyactis. Borrow pit colonizers included species indicative of saline conditions.

A seasonal aspect was noted in the vegetation of Marsh Shores. Senecio congestus, an early season dominant, was replaced by A. brachyactis, A. patula and C. rubrum in September. S. congestus appears sporadically in habitats similar to those of C. rubrum. Although it is usually a winter annual, two summer annual populations were found growing on Marsh Shores at Delta. The species is tolerant and can flower when flooded if floral apices can emerge from the water.

C. rubrum seedling survival in a waterlogged site was low and flooded individuals died. The species exhibits phenotypic plasticity in response to environmental conditions. The tallest, most branched plants developed in the absence of competition on mud flats exposed early in the spring that were subsequently well drained. Impoverished borrow pit soils produced prostrate plants with sparsely lobed, fleshy leaves abundant in anthocyanins. Waterlogged soils limited branching and overall growth.

The effect of different management techniques on plots planted with a range of C. rubrum seed densities was assessed. The importance of reducing emergent cover to maximize growth was demonstrated. Residual seed is abundant in Delta soils and planting is probably not necessary.

Growth chamber experiments indicate that fastest germination is in light with high alternating temperatures. Seeds can withstand two cycles of hydration-dehydration and germinate with 70% success. Seedlings were unable to emerge successfully from a depth of more than 3 mm. Survival decreases with increasing initial seedling density and survival was greater in the laboratory than in the field site studied. Plants growing in water-logged soil had lower survival and less growth than those growing under a moderate water regime. Survival was 27% for seedlings flooded with 1 cm water and 3% with 5 cm water.

Results from these investigations and from the literature are integrated into a final discussion on the ecology and management of *C. rubrum*.

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1. INTRODUCTION

Mud flats are exposed by seasonal and long term drying of marshes. They are a direct result of the changing water levels that keep a marsh alive. Drawdown areas are the germination sites of emergent cover species, like *Scirpus acutus*[1], *S. validus* and *Typha latifolia*. The muds may be colonized by annual weeds (Harris and Marshall, 1963) whose seeds become a potential duck food in the fall. Upon reflooding, the plant remains decay and with the soil become the habitat of numerous invertebrates which provide a high protein source for breeding ducks (Krapu, 1974). The importance of water level fluctuations and the periodic appearance of mud flats has lead to the practice of artificially manipulating water levels for short term gain (creation of drawdown areas) and long term goals (productivity of the marsh).

In the Delta Marsh there has been a local tradition of manipulating small tracts of marsh to encourage the growth of seed producing plants, in particular, *Chenopodium rubrum*. Large scale plans to manage the Delta Marsh are now in the development stage. Their aim is to ensure the high productivity of all aspects of marsh life by simulating natural long term water level changes. The amplitude of water level fluctuations has been dampened by regulation of Lake Manitoba, the Clandeboye dam, silting in of some former channels and various man-made features that have compartmentalized certain areas of the marsh.

1 Nomenclature follows Scoggan (1957). All species mentioned in the thesis, with the authority, are listed in Appendix I. Varieties are not given in the text but are included in the appendix.

The study of mud flats is important in the understanding of changes that will occur as water levels in the marsh are manipulated. Focus was placed on C. rubrum because of its importance as a waterfowl food plant, especially since it has already been the target of small scale management projects at Delta. Study of this species is worthwhile in furthering the knowledge of mud colonizing species and their strategies for survival in this temporary habitat.

Observations were also made on another drawdown invader, Senecio congestus. It becomes dramatically conspicuous at certain times (Walker, 1965) and is a competitor with C. rubrum. The life cycle of this composite provides an interesting contrast with that of C. rubrum and most of the other mud colonizing species, as it is a winter annual, whereas the majority of the others are summer annuals.

This study focuses upon C. rubrum with comparisons made with S. congestus. The objectives were to investigate:

1. The effect of water levels on the life cycle of C. rubrum and to a lesser extent on S. congestus.
2. The implication of these effects for marsh management.

The thesis has been organized into six chapters. This introduction is the first chapter and a review of the literature is second. The third deals in turn with a general treatment of the Delta Marsh and then describes each of the habitat types studied. The methods are outlined in chapter four - the field investigations followed by the growth chamber experiments. The results with discussion are presented in chapter five. Finally, chapter six is an overview of the ecology of C. rubrum and makes some management recommendations.

2. LITERATURE REVIEW

Chenopodium rubrum is a north temperate weedy species irregularly distributed through Europe, Asia Minor, and Central Asia and introduced to North America, South Africa, Mexico and Terra del Fuego. It is listed as occurring in several communities in Britain: arable land, waste places, wet places and maritime habitats (Williams, 1969). In North America it is primarily a plant of wet places, i.e. the exposed mud shorelines of inland marshes and disturbed marsh sites.

Moyle and Hotchkiss (1945) found it fairly common in western Minnesota where it grows in alkaline sloughs and lake margins. Harris and Marshall (1963) studied water level changes on small marshes in north-west Minnesota. They found mixtures of mud flat weeds, including *C. rubrum*, appeared when mid-summer drawdown was combined with rapid drying. The weeds appeared every year of drawdown, but disappeared with reflooding. Duebbert (1969) lists *C. rubrum* as appearing on alkaline flats in Oregon, especially in the less alkaline areas.

A number of workers have studied the prairie pothole marshes of Saskatchewan. Miller (1969) describes the factors that determine the plant species present in a particular basin. *C. rubrum* is listed as appearing in drought years and on summer drawdown zones as one of a complex of coarse weedy forbs. Dodd and Coupland (1966) found *C. rubrum* to be prominent and occasionally dominant in halophytic vegetation where water seldom accumulates on the water surface. Stewart and Kantrud (1969) proposed a classification of potholes in the glaciated prairie region. They place *C. rubrum* among the species common to the drawdown phase of shallow and deep marshes where salinity of surface waters is slightly to moderately brackish.

C. rubrum has been mentioned in a number of studies that have been carried out at Delta. Löve and Löve (1954) describe the vegetation of the Delta Marsh area where C. rubrum is a constituent of the "frontier associations" of the marsh. Walker (1959, 1965) followed the succession of plant species and community development in the marsh following a series of high water years that had eliminated most marsh plants. C. rubrum was the fourth most prevalent species at this time - a colonizer of newly exposed areas.

A classic paper on mud flat vegetation (Salisbury, 1970) describes the biological adaptations of some of the most common British members of this habitat. It notes the extreme plasticity of C. rubrum which grows large on early exposed sites but can produce viable seeds on the tiny plants that germinate late in the season. The most characteristic species of these exposed muds have certain features in common. They are annuals or function as annuals, are often self-compatable and frequently cleistogamous, and have a high reproductive potential. At drawdown, which may not occur for centuries, carpets of seedlings appear through quasi-simultaneous germination of the long lived seeds.

The presence of Senecio congestus at Delta was first recorded by Löve and Löve (1954). It was rarely seen before 1953, but now makes sporadic spectacular appearances in shallow water or on waterlogged soil. Walker (1965) suggested seed availability was responsible for the fact that S. congestus is abundant in one site and absent in another, in spite of similar soils and drying time. It has been observed growing on the shoulders of blasted potholes at Delta (Hoffman, 1970).

Smith (1971) reported S. congestus to be common on mud flats around potholes in Alberta. Miller (1969) found it appears with C. rubrum as a pioneer of the drawdown zone of Saskatchewan marshes. Stewart and Kantrud (1969) list it with C. rubrum in the drawdown phases of shallow and deep marshes where surface water is fresh to slightly brackish. On the Agassiz Refuge in Minnesota S. congestus was not known until Harris and Marshall's (1963) study. They suggested it probably survived in small areas along ditches and ponds and then as drawdown began the populations gradually increased until all available mud flats were colonized. Recent studies of S. congestus have focused on its role as a colonizer of silty mud outwash in the arctic (Lambert, 1976).

A number of germination studies have focused on C. rubrum. Cumming (1959) found its germination negligible at constant temperatures less than 35°C in darkness and at temperatures less than 25°C under 8-hour, short days. Complete germination occurred in all alternating temperatures with light, while in the dark, germination occurred only at the lower alternating regimes. C. rubrum requires light to germinate, but at low alternating temperatures this condition is removed.

Germination is promoted by white or red light and inhibited by blue or infra-red (Cumming, 1959). Further, there is more germination in light with red/far red ratios similar to that of sunlight (1.3) than sunlight through green vegetation (0.07 to 0.12) (Cumming, 1963) suggesting the possibility of a reduction in germination in areas shaded by green plants. Williams (1969) notes that C. rubrum seed sown in closed communities, such as grasslands, fail to establish.

C. rubrum produces large seeds and small seeds, whose germination behavior is not statistically different, although there is a slight tendency for the large seeds to germinate sooner than the small ones

(Salisbury, 1970). Williams (1969) states that the horizontal seeds produced by the terminal flowers germinate more readily than the vertical, lateral ones and are analagous to the large brown seeds of Chenopodium album.

Seeds remain viable for at least 50 years (Williams, 1969). Germinating seeds may suspend growth under adverse conditions and remain viable for extended periods, germinating rapidly when transferred to optimum conditions (Cumming, 1963). Experiments with nutrient solutions indicate optimum germination occurs with nitrate or complete culture solution. Seedlings are reported to emerge from soil depths of 0.5 to 4 cm (Williams, 1969).

C. rubrum exhibits phenotypic plasticity in response to soil nutrients. Leaf size and fleshiness and degree of branching of the inflorescence are especially variable (Williams, 1969). Plants grow large on sites exposed early in the season (Salisbury, 1970) and in nitrogen rich soil, but growth is reduced at low concentrations of calcium, phosphorous or potassium (Williams, 1969). Two growth forms have been observed at Delta (Walker, 1965). Tall individuals (1.5 to 2.0 m), growing singly, were triangular in shape, coarse, woody and much branched. Smaller plants (0.5 m) were slender, unbranched and numerous.

Cumming (1961) states that species of Chenopodium in temperate North America are short day plants, but show a latitudinal response to photoperiod with the critical day length being longest in the north. He investigated the effect of photoperiod on growth and found that under the extreme long days of the north, the rate of floral initiation, stem elongation and leaf production were greater than in sites further south. Size of leaves and anthocyanin production were greater with short southern days.

Latitudinal response in relation to seed weight was studied by Cook (1975). Seed from 50°10" N, where the critical photoperiod is 16 to 17 hours, was grown in 15-hour and 12-hour day lengths. The 15-hour plants produced many more seeds at a significantly smaller seed weight than the 12-hour plants. In addition, the 15-hour plants developed more slowly with more nodes and greater internodal length. Leaves were longer, narrower and less lobed in the 15-hour light day plants.

Cook (1976) later reported on the relationship between potential growth rate, correlative control of form, competitive vigor and resultant seed production. The potential seed number is determined by the number of bud primordia present at induction. This is partly a function of latitude, as the critical photoperiod is shorter in the south and plants have longer to develop. It is also a function of the availability of resources. When resources are abundant the degree of apical dominance is reduced and there is abundant growth of axillary bud primordia ready to differentiate into floral structures. Potential seed number is then a function of the rate and duration of organ initiation at induction. At this time there is a metabolic change and all processes speed up for a certain period of time. The rate and duration of this increased activity will determine potential seed number. There is a latitudinal response here as southern populations generally have slower rates of development, but for a longer period of time.

Chenopodium rubrum has been used widely as an experimental subject for studies on the physiology of flowering (see Cumming, 1969 for review paper) because it can be induced to flower very rapidly (Cumming, 1959). Williams (1969) summarized the biology of the species. Recent studies have provided insight into phytochrome mediated responses (Frosch and Wagner, 1973 a&b).

Seeds of *Chenopodium* spp. are relished by songbirds and some ducks, while the seeds and leaves are eaten by gamebirds, small mammals and deer (Martin, Zim, and Nelson, 1951). Remains of *Chenopodium* sp. have been found in the rumen contents of white-tailed deer at Delta (Kucera, 1974). *C. rubrum* seed is an important duck food (Ward, 1968). It is grazed by cattle and mature seeds can survive in the dung (Williams, 1969).

General studies on marsh vegetation have considered the factors influencing plant distribution. The results of some studies differ widely because of basic differences in the material being studied. For instance, AuClair *et al.*(1976) found that disturbance, especially by fire, is most important in sedge meadows, while for aquatic emergents, water depth is the prime distributional factor. Ungar (1965) noted that where salt concentrations were high this seemed to be the overall controlling factor, but in sites where salinity was low, moisture played an important part.

Salt was considered the major influence by Keith (1958) and Dodd and Coupland (1966). Nutrients were most important in the marshes studied by Walker and Wehrhahn (1970) and Dirschl (1972). Water chemistry was cited by Pearsall (1918), Moyle (1945), Moyle and Hotchkiss (1945), Miller (1969) and Spence (1967). Turbulence was mentioned by Spence (1967) and sediment by Pearsall (1918) and Van der Valk and Bliss (1970). Walker and Wehrhahn (1970) found disturbance the main factor and Van der Valk and Davis (1976) maintain it is composition of the seed bank that determines floristic composition. The factor most frequently cited as controlling plant distribution is water - its permanence, depth, and fluctuations: Uhler (1944), Penfound (1953), Dane (1959), Weaver (1960), Weller and Spatcher (1965), Walker (1965), Miller (1969), Stewart and Kantrud (1969), Dodd and Coupland (1966), Dix and Smiens (1967), Munro (1967), Dirschl (1972), and Van der Valk and Davis (1976).

It is not surprising, therefore, that although marsh management practices include burning, planting and tilling, manipulation of water levels is most frequently used (Nelson, 1954; Kadlec, 1960; Emerson, 1961; Chabrek, 1962; Harris and Marshall, 1963), particularly the drawdown. Drawdowns improve or alter cover for nesting and moulting waterfowl and their broods. The drawdown is best known for the resultant abundance of annual food plants which, when reflooded, are highly attractive to migrating waterfowl and attendant hunters (Yoakim and Dasmann, 1969; Krapu, 1974). The following spring the vegetation provides substrate for invertebrates which are a required food for breeding waterfowl and which attract wading birds (Weller and Spatcher, 1965; Burgess, 1969; Krapu, 1974).

It is well known that exposure of wetland soils can lead to their improvement. There is a reduction in toxic iron and manganese (Cook and Powers, 1958). A marked increase in soil nitrates is the result of aerobic nitrification and is accompanied by a less definite, though favourable, response of other nutrients. Organic decay releases nutrients by changing them from a mineralized to an available form and frees ions held by colloidal organic material. There is a definite increase in plant nutrients in water as a result of drawdown (Kadlec, 1960).

Time of invasion, species composition and plant density were found to differ according to the season of exposure, drainage and soil texture (Iwata and Ishizuka, 1967). Early spring exposure of mud tends to favour emergents, especially when combined with rich soil types, slow rates of mud flat drainage and small amounts of stranded algae. Annual weeds are favoured by exposure after mid-summer - the later the drawdown the less dense the vegetation which becomes established (Harris and Marshall, 1963). Fall and over winter drawdowns rejuvenate submergent production (Green et al, 1964). Burgess (1969) stresses that the time of drawdown is influenced by local conditions and when used as a management tool it varies with the species desired. Van der Valk and Davis (1976) urge caution in attempting to predict the results of artificial drawdowns using data from studies on other marshes because composition of seed banks can be highly variable.

Planting of desirable species has become a standard management technique. Molye and Hotchkiss (1945) suggest planting should only be attempted in areas where a suitable species is known to be absent and where such a species can reasonably be expected to prosper. Burgess (1969) found attempts to plant domestic species futile as they could not stand the floods, drought and infestations of weeds. He exhorts the use of natural moist soil food plants which can adapt to natural changes. Yoakim and Dasmann (1969) give details of planting techniques for many species.

Delta has been the site of many management programs. Ward (1968) used fire to reduce stem density and open up stands of Phragmites communis and other emergents. In open conditions C. rubrum invaded the emergent stands. Hoffman (1970) blasted potholes in Scolochloa festucacea meadows for waterfowl use and recorded the species that colonized the pond shoulders. *C. rubrum* was one species that appeared in the first year after blasting and again in the second year, but with reduced frequency and cover.

3. STUDY AREAS

3.1 General Description of the Delta Marsh

The Delta Marsh, at the southern end of Lake Manitoba (Figure 1) is underlain by Jurassic dolomite of the Amaranth formation (Weir, 1960). The continental ice sheet and then Glacial Lake Agassiz covered the area, leaving deposits of glacial drift and lacustrine sediments (Ehrlich, Poyser and Pratt, 1957). Soils discussed in detail by Walker (1965) are basically gleysols and regosols. Gleysols are soils which are saturated with water and are under reducing conditions for some or all of the year and may have an organic surface layer. Regosols are well- and imperfectly drained mineral soils with good to moderate oxidizing conditions, having weak horizon development (Can. Dept. of Agric., 1974).

Weir (1960) describes the climate as typically continental with a hot summer (mean July air temperature 20°C) and cold winter (mean January air temperature -17°C). Lake Manitoba has a local effect in modifying the climate by retarding spring and fall temperature changes thus reducing frost damage (Manitoba Water Commission, 1973). Average annual precipitation is 50 cm, 70% of which falls as summer rain (Weir, 1960). Daily maximum and minimum of temperatures and rainfall for the summer of 1975, as recorded at the University Field Station in the Delta Marsh, are presented in Figure 2. There was abnormally high rainfall from mid-July through August. June is usually the wettest month.

The 15,000 ha Delta Marsh is a series of shallow bays connected by winding channels and set within a *Phragmites communis* matrix (Walker, 1965). The marsh has been in existence for at least 2,400 years and

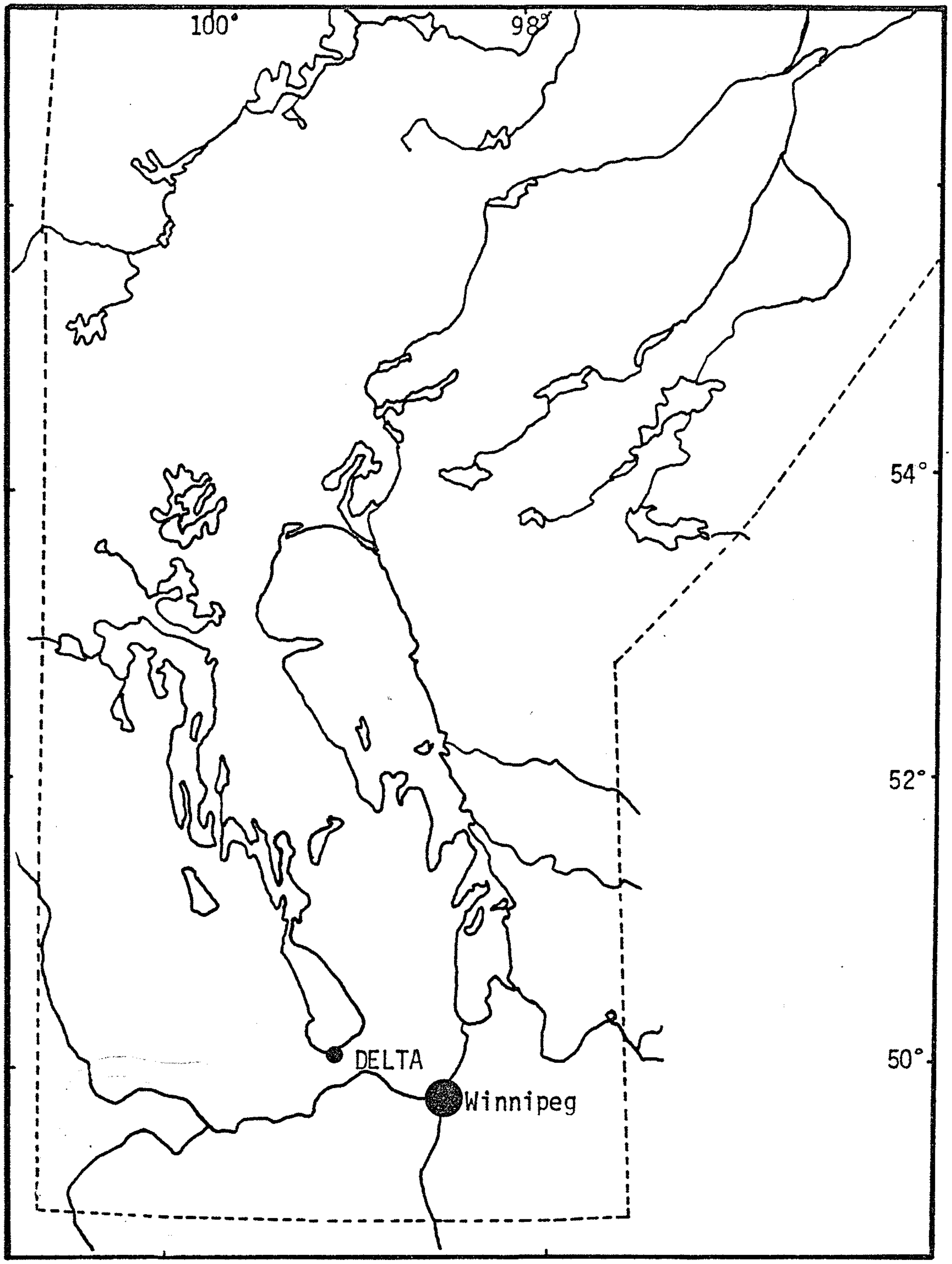


FIGURE 1: Location of the Delta Marsh in southern Manitoba.

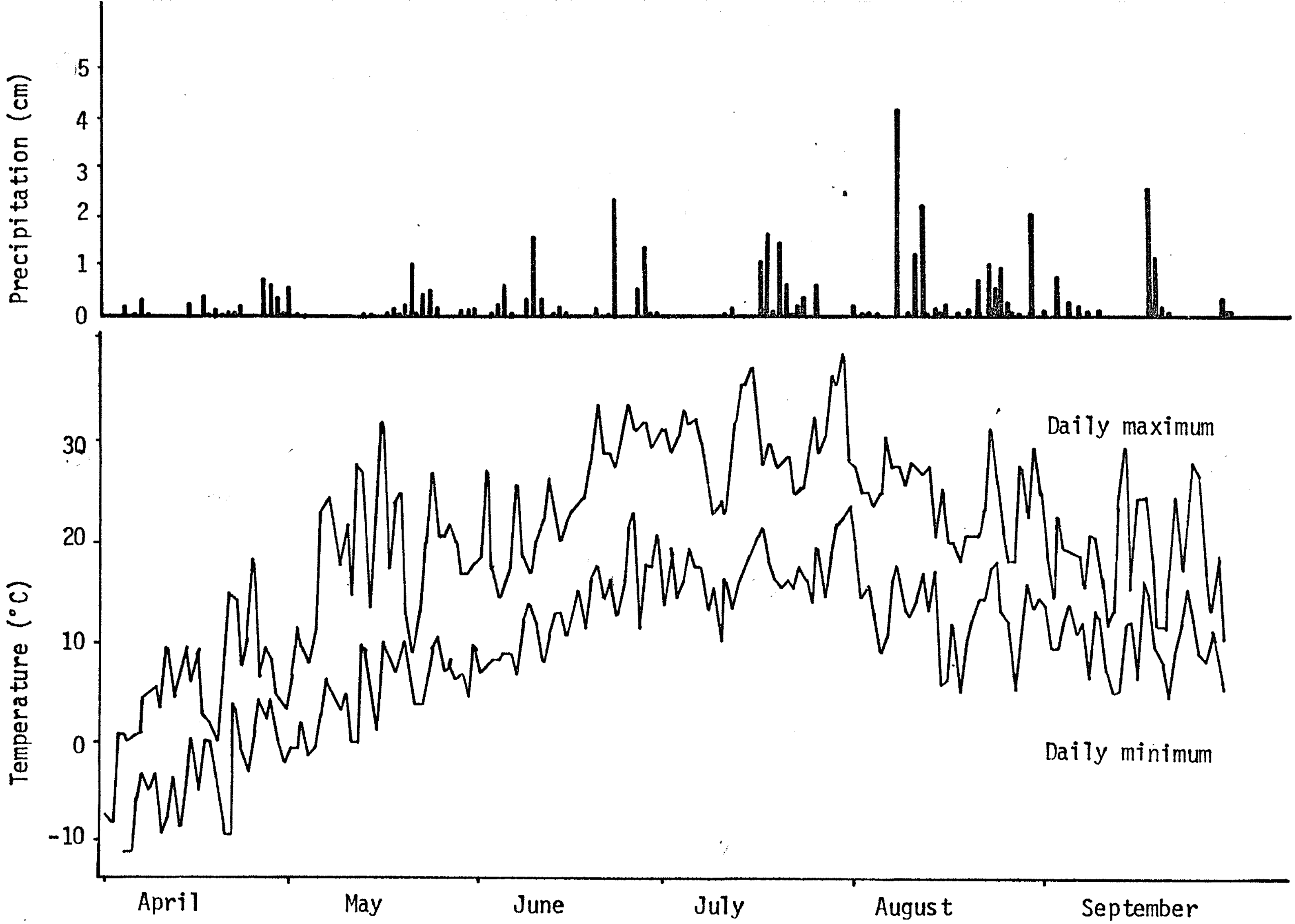
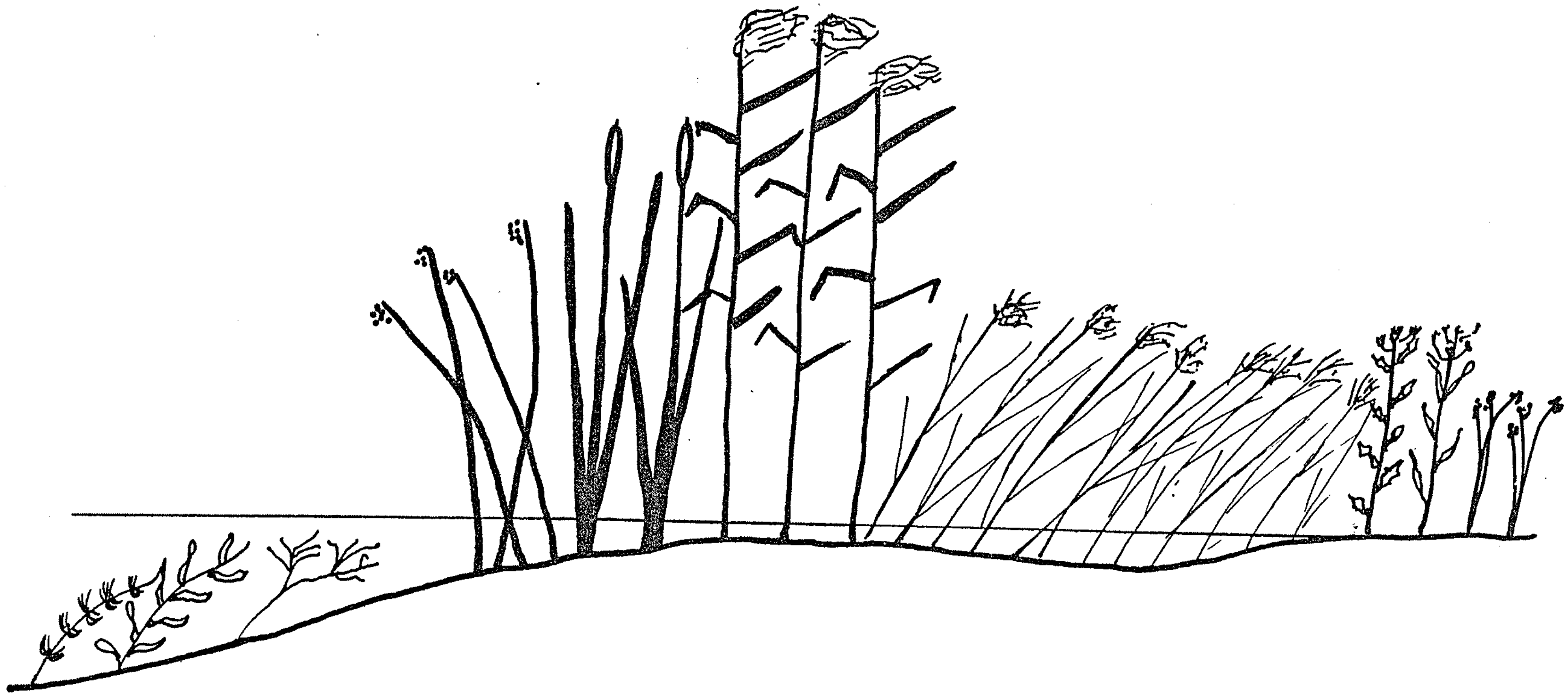


FIGURE 2: Daily maximum and minimum temperatures and rainfall at Delta, summer 1975.

has been maintained as such because of periodic flooding and the lack of inwashed mineral sediments (Sproule, 1972). The marsh is separated from Lake Manitoba by a series of forested sand beach ridges. Along the lake edge the moving sand is colonized by Salix interior and on the stabilized dunes a community dominated by Acer negundo, Fraxinus pennsylvanica, and Salix amygdaloides has developed. Populus deltoides, Quercus macrocarpa and Ulmus americana occur sporadically on the ridges. The shrub layer is well developed in places with Cornus stolonifera, Sambucus pubens, Rosa acicularis, Prunus virginiana and Rhus radicans being most conspicuous.

The marsh maintains contact with the lake by several small channels which cut through the beach ridge system and thus marsh water levels fluctuate in harmony with those of the lake. The marsh experienced its last period of severe flooding in the mid 1950s (Walker, 1965). Water levels in the bays can change very quickly in response to a strong north wind pushing water through the channels and into the marsh.

The vegetation of the Delta Marsh has been described by Löve and Löve (1954) and Walker (1959 and 1965) and the distribution of submerged aquatics mapped by Anderson and Jones (1976). Figure 3 shows a typical zonation of vegetation with submerged aquatics like Potamogeton pectinatus, P. richardsonii, Myriophyllum exalbescens and Ceratophyllum demersum in association with the deep water emergent Scirpus acutus. Typha latifolia is found in shallower water, gradually giving way to Phragmites communis. Extensive seasonally flooded meadows are dominated by Scolochloa festucacea. The surrounding drier meadows have a diverse flora with such species as Sonchus arvensis, Cirsium arvense, Urtica dioica, Stachys palustris and Spartina pectinata.



SUBMERGED AQUATICS	EMERGENTS	WET MEADOW	UPLAND MEADOW
Ceratophyllum demersum	Scirpus acutus	Scolochloa festucacea	Cirsium arvense
Potamogeton richardsonii	Typha latifolia		Sonchus arvensis
P. pectinatus	Phragmites communis		Urtica dioica
			Stachys palustris
			Spartina pectinata

FIGURE 3: Zonation of vegetation in the Delta Marsh.

Depressions between the beach ridges that are low enough to hold water support marsh vegetation. In addition to the emergent perennials already mentioned, Scirpus fluviatilis, Sparganium eurycarpum, and Carex spp are found. The associated herbaceous species are different from those of the rest of the marsh because of the sandy substrate and the proximity of a different group of wet ground species from the forest. Species such as Galium trifidum, Rorippa islandica, Bidens cernua, and Epilobium glandulosum are found.

Following periods of high water, during droughts and through seasonal drawdown, mud flats appear along the shores of bays and in depressions throughout the marsh. In these areas denuded of vegetation, the perennial emergent species germinate as succession begins again. But these wet soils are temporarily dominated by an assemblages of colonizing annual species like Chenopodium rubrum, Atriplex patula and Aster brachyactis. Senecio congestus makes an occasional very showy appearance to the exclusion of practically all other species. In places where soils are slightly alkaline Suaeda depressa, Hordeum jubatum, and Salicornia rubra are among the pioneers.

3.2 Description of Study Areas

High water conditions in 1975 limited the distribution of Chenopodium rubrum in the Delta Marsh. Investigations were therefore on a small number of areas, which are divided into three groups and discussed below. Study Areas are the locations of the major investigations, while Study Sites are the micro habitats, within the Study Areas, where marked individuals of C. rubrum were followed (Figure 4).

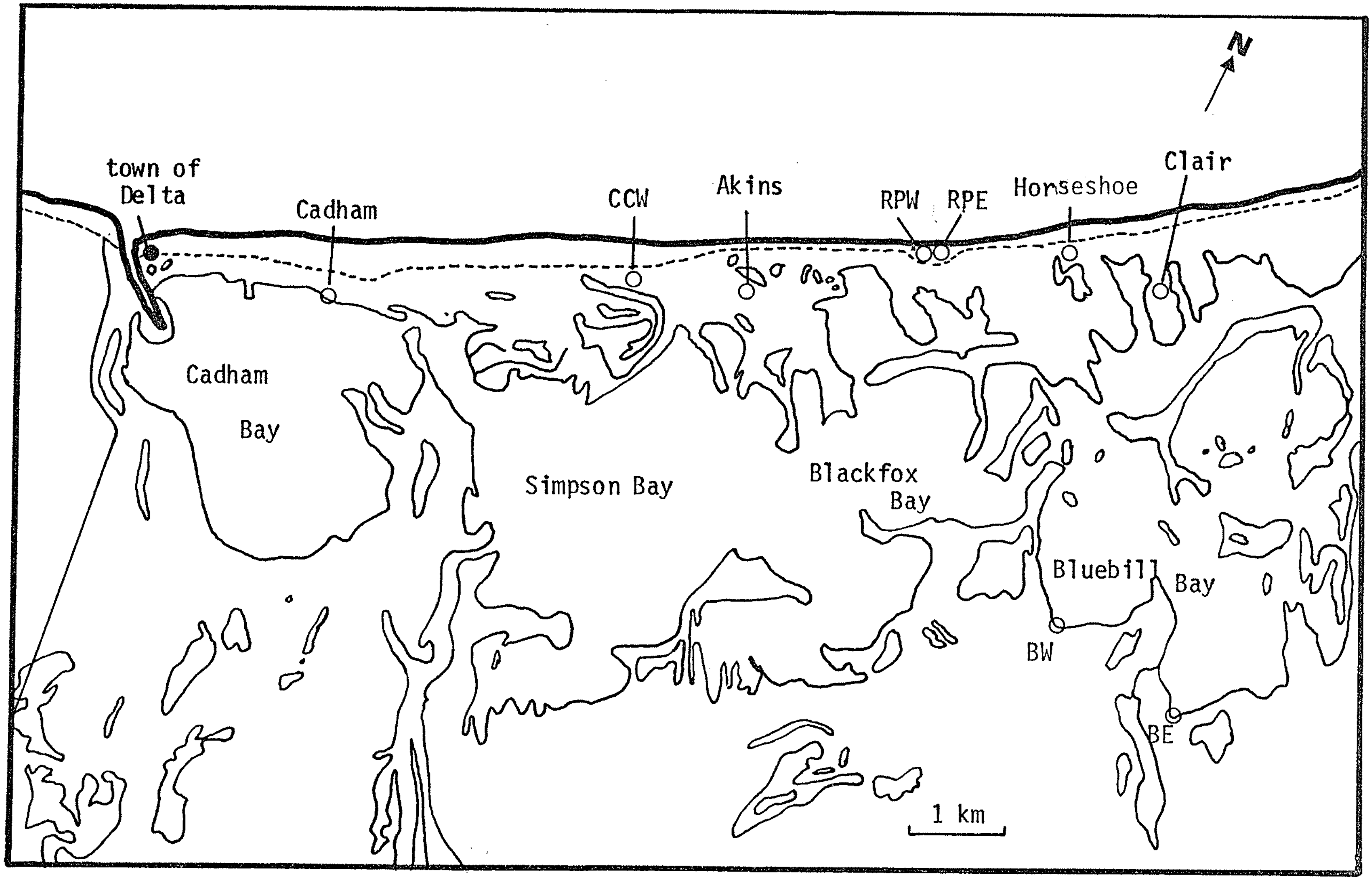


FIGURE 4: Map of part of the Delta Marsh showing location of Major Study Areas

3.2.1 Ridge Marshes

Round Pond East (RPE) and Round Pond West (RPW), approximately 8.8 km north-east of the village of Delta, are two adjacent marshes within the beach ridge complex. The areas measure 75 m x 40 m and 275 m x 25 m and are both dominated by *Phragmites communis*. These marshes are confined by the sand ridges and a dike system. They were frequently manipulated during the 1960s, but have been undisturbed from 1969 until this investigation began.

Three *C. rubrum* growth Study Sites were in the ridge marshes Site E was located in a particularly low area at RPE where surface water was present until the end of June. Site F was located on the sandy material piled up June 10, 1975 when the ditch draining RPE was dredged. Site G at RPW was a slight hummock two meters away from the experimental plots.

3.2.2 Wet Meadows

Clair Lake (Clair), an area 30 m x 15 m, 11.3 km north-east of Delta, and Horseshoe Pond (Horseshoe), areas 10 m x 5 m to 150 m x 25 m, 10.3 km north-east of Delta are Study Areas located in wet meadows. Persistent water in slight depressions had caused the death of the dominant species, *Scolochloa festucacea*. Site A was located on a small area raised above the flooded meadow at Clair, while Site B was in a similar situation at Horseshoe.

Man-made openings in *S. festucacea* dominated meadows of 100 m x 50 m at Akins Bay (Akins, 7.3 km north-east of Delta) and 60 m x 100 m at Cook's Creek West (CCW, 5.8 km north-east of Delta) were examined. These Areas were contained within a dike system and have been manipulated for at least the last ten years.

Site D was a small part of CCW where *C. rubrum* germinated after the site had drawndown naturally. Site C was 10 m away from D in a part of CCW that was mowed and tilled by July 11, 1975, two weeks after all surface water had disappeared. Site H was located on one of the dikes at Akins Bay where mud had been piled up during dredging operations during the late summer of 1974.

3.2.3 Marsh Shores

Along some of the shores of the large bays of the Delta Marsh the perennial emergents, *Phragmites communis* and *Typha latifolia*, had been killed by high water and storms, leaving unvegetated mud flats. Three such areas were investigated. The north shore of Cadham Bay (Cadham, 2.5 km north-east of Delta) had flats 3 m wide scattered along about 100 m of shoreline. At the south end of Bluebill Bay (11 km east of Delta) two large mud flats had been created. The western area (BW) was 200 m long while the eastern area (BE) was 250 m, both being up to 15 m wide.

4. METHODS

4.1 Environmental Parameters

4.1.1 Drawdown

During the spring of 1975, sites that appeared to have the potential for *Chenopodium rubrum* growth were located and reference stakes installed for water level measurements. Wet meadow Study Areas, Horseshoe Pond, Clair Lake, and CCW, were measured and two similar wet meadows which were not used for any further investigation. The progress of drawdown in these marsh areas was monitored at approximately ten day to two week intervals through spring and early summer. In addition, readings were taken until the end of September from a water level gauge permanently situated in Cadham Bay.

4.1.2 Soil and Water Analysis

Composite surface soil samples were taken at the major Study Areas and at various *C. rubrum* habitats during the summer of 1975. In the laboratory pH was determined for three subsamples from each composite sample. A saturation paste was made using distilled water and a Beckman pH meter used for the determinations. The three subsamples were combined, placed in a Buchner funnel and the saturation extract obtained for conductivity readings with a Radiometer Conductivity meter.

Water content was obtained for three replicates. A weighed beaker was filled with field soil, it was reweighed, placed in a drying oven at 40°C and dried to a constant weight. Percent moisture was calculated by the formula:

$$\% \text{ moisture} = \frac{\text{wet wt. of soil} - \text{oven dry wt. of soil}}{\text{wet weight of soil}} \times 100\%$$

Organic matter content was determined for a subsample from each of the oven dried replicates. Dry soil was placed in a preweighed crucible and weighed. Samples were ignited in a muffle furnace at 500°C, cooled in a dessicator, and reweighed. Percentage organic content was calculated by the formula:

$$\% \text{ organic} = \frac{\text{wt. of oven-dry sample} - \text{wt. of ignited sample}}{\text{wt. of oven-dry sample}} \times 100\%$$

To investigate soil variability within a marsh site, intensive sampling was carried out at CCW on August 14, 1975. A sample was taken every meter along a 25 m transect and subsequently pH and conductivity determined as described above.

At a selection of sites that appeared to have the potential for *C. rubrum* growth, water samples were taken before summer drawdown and pH and conductivity were determined.

4.2 *Chenopodium rubrum* Habitats

4.2.1 Description

A list of species, with percent frequency for each species, was compiled for six major Study Areas (BE, BW, RPE, RPW, Akins and CCW) from sampling conducted in the areas in September, 1975. Sampling at BE and BW is described below in section 4.2.2 and for the rest of the sites in section 4.4.1.

4.2.2 Marsh shores

Preliminary surveys in 1973 and 1974 indicated that the exposed mud shores of large bays were an important *C. rubrum* habitat. In 1975 three marsh shores were studied - one on the north shore of Cadham Bay and two along the south shore of Bluebill Bay (Figure 4). All the shores were sampled in July, but during the summer the Cadham Shoreline was destroyed, so only the Bluebill Areas were reassessed in September.

The vegetational composition and seasonal changes in species numbers and biomass were assessed by analyzing the contents of 20 quadrats, each 625 cm^2. The random quadrats were located by means of grid coordinates determined from a random numbers table. Above ground portions were clipped and density and dry weight determined for each species.

4.2.3 *Senecio congestus*

In conjunction with the general sampling program outlined above special observations were made and some additional sampling undertaken to investigate the growth and survival strategy of *Senecio congestus*. Height was measured and flower heads counted (when present) for each individual, except for the spring flowering population at BE on July 13, when only height was measured. Sampling is summarized in Table I.

4.3 Growth and Phenology of *Chenopodium rubrum*

4.3.1 Seedling survival

In 1975 seedling survival was studied at RPW. On August 5, 100 25 cm^2 wire quadrats were set within the *C. rubrum* population and seedlings counted. Survival was determined on August 22.

4.3.2 Habit and phenology

Twenty plants from each of eight populations located in the Study Sites described previously were marked and their performance recorded

TABLE I Summary of sampling of height and flower heads for *Senecio congestus* on three marsh shores, 1975.

	Spring Flowering	Summer Annual	Fall Rosettes
Bluebill East			
June 13	5 quadrats*	3 quadrats	
July 21	20 quadrats		
September 4		12 individuals	20 quadrats
Bluebill West			
July 13	20 quadrats	7 individuals	5 quadrats
September 9			
Cadham Bay			
July 3	20 quadrats		

*quadrat size = 625 cm^2

at three time periods from the beginning of August to the beginning of September. Plant height and horizontal diameter were measured, leaves counted, relative branching scored on a scale from one to five and reproductive condition noted.

Analysis of variance was computed on data for plant height, diameter and leaf number transformed to $\log_{10}$ (raw data was significantly heterogeneous), from the first and last sampling periods. Comparisons of all means were then made by the Student-Newman-Keuls test or the Sequential Q Method, a modified t-test (Snedecor and Cochran, 1967).

4.4 Experimental Plots

4.4.1 Experimental design

In conjunction with the Delta Waterfowl Research Station four tracts of marsh were artificially manipulated by various sequences of burning, cutting, tilling, flooding and draining to set back succession and create habitat suitable for C. rubrum. The sites were used to study the effect of seed density and management practices on the production of C. rubrum in planted populations. A listing of the management procedures and experiment timings are given in Table II.

Seed for the experiments was collected from slender, unbranched specimens in one site in the Marsh in the late fall of 1974 and stored in large plastic bags in an unheated shed over the winter. The seed was highly contaminated with Atriplex patula seed, but passage through a 1 mm mesh sieve removed all impurities. The C. rubrum seed, including the papery pericarp, was weighed into the appropriate amounts for the treatments and bagged.

TABLE II: List of events at the four managed sites in the Delta Marsh, 1975.

	RPE	RPW	Akins	CCW
1974 Summer and Fall	burned and tilled	burned and tilled	no treatment	tilled and later flooded
1975 Spring	pumped dry by June 12	natural drawdown	natural drawdown	natural drawdown
Summer	no treatment	tilled July 8	burned and tilled by July 20	cut and tilled by July 11
Planting	June 16	July 12	July 24	not planted
Harvest	Sept. 13, 14	Sept. 28,29	Sept. 11	Sept. 22
Reflooding complete	Sept. 18	Sept. 30	Sept. 13	Sept. 24

On the managed sites plots 10m x 10m were measured out and flagged. The number and positioning of the plots was partly determined by the configuration of the sites, which were different sizes and shapes. The treatments were assigned to the plots using a random numbers table. Table III lists the treatments applied at each site.

One of the treatments was an application of 250 gm C. rubrum seed and 250 gm Atriplex patula seed per plot. The effect of growing these two closely related and associated species was to be assessed. This additional analysis had to be abandoned due to lack of time.

The progress of the plantings was observed through the summer and the treatments were assessed by harvests of above ground standing crop conducted in September. Ten 625 cm^2 quadrats were clipped from each plot and bagged separately. The contents of each bag were subsequently examined and all species listed. Density and dry weight were determined for C. rubrum, Phragmites communis, Typha latifolia, Scolochloa festucacea and Scirpus validus. The remaining species were dried and weighed as a group.

4.5 Growth Chamber Studies on Chenopodium rubrum

4.5.1 Seed germination

All the C. rubrum germination studies were carried out using seed collected in the fall of 1974 as described in the previous section. After June 1975 the seed was stored at room temperature. It was not sorted as to size or colour and the pericarp was not removed. All experiments were executed with 8 cm petrie dishes holding 5 layers of filter paper moistened with 10 mls of distilled water. Unless otherwise indicated the seeds were watered each day. The effects of light intensity, temperature and periodic dehydration on percentage germination were investigated as indicated below:

TABLE III: Numbers of plots receiving different densities of *Chenopodium rubrum* seed at the four managed sites in the Delta Marsh, 1975.

Grams of seed applied to each plot (100 m^2)	MANAGED SITES			
	RPE	RPW	Akins	CCW
500	4	3		
250	4	3	3	
125	4	3	3	
62.5		3		
31		3	3	
250 + 250 *Atriplex patula*	4	3		
Control (no seed applied)	3	3	1	4
Total Plots	19	21	10	4

Light intensity

Temperature: $20^{o}C$ day, $10^{o}C$ night

Photoperiod: 16 h.

Illumination: Five replicates of 25 seeds were subjected to six light intensities: darkness, 2.70, 3.66, 5.81, 9.58 and 14.05 kilolux. Source of light in the growth chamber was from a combination of incandescent and florescent bulbs. Petrie dishes in the dark treatment were completely enclosed in aluminium foil while the other variations in intensity were achieved by covering with layers of cheesecloth.

Observations: The number of seeds germinated was counted several times from day 6 to day 18 of the experiment.

Temperature

Temperature: Five replicates of 100 seeds each were germinated under five temperature regimes: $30^{o}C$ day - $20^{o}C$ night, $20^{o}C$ day - $10^{o}C$ night, $15^{o}C$ day - $5^{o}C$ night, $15^{o}C$ day - $10^{o}C$ night, $20^{o}C$ constant.

Photoperiod: 16 h.

Illumination: 16.15 kilolux

Observations: Percent germination was determined several times to a maximum of 18 days after the initiation of the experiment.

Hydration - Dehydration

Temperature: $20^{o}C$ day - $10^{o}C$ night.

Photoperiod: 16 h.

Illumination: 16.15 kilolux

Watering: Five replicates of 100 seeds each were subjected to three watering regimes as outlined in Table IV.

Observations; Percent germination was determined 12 days after daily watering had commenced for each treatment.

TABLE IV: Watering regimes used in Hydration-Dehydration experiment on *Chenopodium rubrum* seed.

		TREATMENT	
Day	Control	2	3
1	Watered	Watered	Watered
2	↓	Not watered	Not watered
3	↓	Not watered	Not watered
4	↓	Watered	Watered
5	↓	↓	Not watered
6	↓	↓	Not watered
7	↓	↓	Watered
8	↓	↓	↓
9	↓	↓	↓
10	↓	↓	↓
11	↓	↓	↓
12	↓	↓	↓
13		↓	↓
14		↓	↓
15		↓	↓
16			↓
17			↓
18			↓

4.5.2 Seedling response

Standard growth chamber conditions for the three seedling experiments were as follows:

Temperature: 20°C day - 10°C night.

Photoperiod: 16 h.

Illumination: 16.15 kilolux.

Depth of emergence

Treatment: Using styrofoam cups and sterilized marsh soil five replicates of 25 seeds each were carefully planted at depths of 0, 3, 10 and 20 mm and covered with finely sieved soil. After a thorough and careful watering each cup was loosely covered with clear plastic to eliminate the need for frequent watering and disturbance of the soil surface.

Observations: On days 9, 13, and 25 percent emergence was assessed.

Density

Treatment: Seedlings at the cotyledon stage were transplanted into one pint milk cartons filled with marsh soil. Plantings of 10 replicates of 5, 25, 100 and 200 seedlings per container were made to create densities of 0.1, 0.5, 1.8 and 3.6 plants per cm^2. Plants were watered as necessary.

Observations: Percent survival after one month was determined.

Water regime

Treatment: Six treatments, with 10 replicates each, were set up using marsh soil in 12 oz plastic cups. Seeds were scattered on the soil surface at the commencement of the experiment and one week after allowed to germinate were thinned to 10 plants per cup. The treatments (Table V) were differing watering regimes and floodings. Replicates in the "moderate" regime were watered when the soil surface began to feel dry. The waterlogged cups were maintained with water just glistening at the soil surface.

Observations: In the sixth week the percent survival in each container was determined and the height of survivors measured.

TABLE V: Sequence of events for the six treatments in the water regime experiment on Chenopodium rubrum

#	Week 1	2	3	4	5	6
1	Flooded with 1 cm water	Allowed to drawdown and seeds to germinate	Seedlings thinned to 10 plants/cup Moderate Watering →	→	→	→
2	Moderate Watering	Thinned to 10 plants/cup Flood with 1 cm water	1 cm water maintained	Allowed to Drawdown Moderate Watering →	→	→
3	Moderate Watering	Thinned to 10 plants/cup Moderate Watering	Moderate Watering	Flooded with 1 cm water →	→	→
4	Moderate Watering	Thinned to 10 plants/cup Moderate Watering →	→	Flooded with 5 cm water →	→	→
5	Moderate Watering	Thin to 10 plants/cup Moderate Watering →	→	→	→	→
6	Moderate Watering	Thinned to 10 plants/cup Continuously Waterlogged →	→	→	→	→

5. RESULTS AND DISCUSSION

5.1 Environmental Parameters

5.1.1 Drawdown

Mean water levels for the five marsh sites and for Cadham Bay are presented in Figure 5. In May the marsh sites held different amounts of water, but by mid July surface water had evaporated. Water levels rose subsequently with the commencement of the excessive rainfall of 1975 (Figure 2) and recording was discontinued.

The water levels in Cadham Bay remained stable until mid July, declined to a mid August low and then rose through the fall. Possibly this large bay exhibited a lag response compared with the more immediate reaction of the small isolated marsh areas. Cadham Bay is connected to Lake Manitoba and would reflect lake levels, including the effect of strong wind tides.

5.1.2 Soil and water analysis

The results of the soil analysis are presented in Table VI. The pH values ranged from 7.0 to 8.0. Most of the ridge marshes had pH close to 7, but the borrow pits produced values near 8. Conductivity readings for all soils ranged from 2.0 to 12.3 mmhos cm^{-2}. Walker (1965) recorded pH of 6.9 to 8.3 and conductivities from 0.21 to 54.50 mmhos cm^{-2} for sites in the Delta Marsh. The ranges of pH and conductivity here reported are not as great as those found by Walker presumably because of more restricted sampling in this study.

Borrow pit soils had the lowest percent moisture and percent organic content so were the only sites in which lack of moisture may

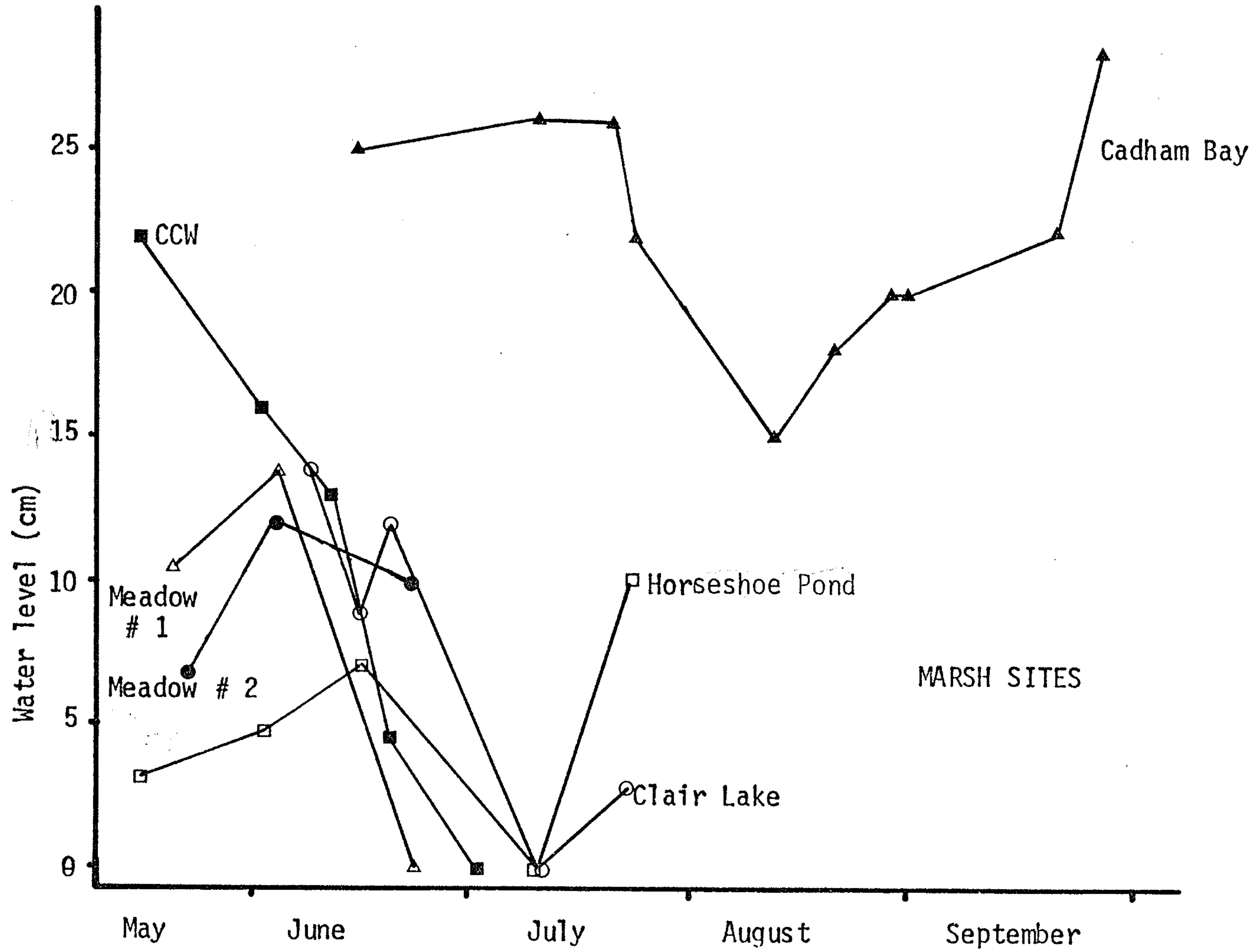


FIGURE 5: Water levels in several sites in the Delta Marsh, 1975.

TABLE VI: Soils data: pH, conductivity, percent moisture and percent organic content, Delta, 1975.

SAMPLE AREAS	Date	pH*	Conductivity mmhos cm^{-2}	% moisture*	% organic*
<u>Wet Meadows</u>					
CCW	July 3	7.7	6.4	65.9	34.2
	July 28	7.6	12.3	50.3	23.6
Horseshoe	July 11	7.7	6.0	81.7	63.5
	Aug. 12	7.7	5.3	84.3	71.9
Clair	July 11	7.9	7.1	81.3	62.0
	Aug. 12	7.6	7.8	82.8	60.6
Akins	July 24	7.8	8.3	79.7	54.8
Others 1	July 2	7.0	6.3	84.3	64.7
	July 28	7.1	6.1	74.7	62.7
2	June 24	7.2	2.7	67.7	29.1
3	June 24	7.1	5.4	86.6	60.7
4	June 24	7.3	9.7	86.4	60.5
5	July 11	7.7	4.8	83.9	67.9
<u>Ridge Marshes</u>					
RPE	July 3	7.3	5.1	71.7	39.8
	Aug. 12	7.7	5.3	84.3	71.9
RPW	July 24	7.0	2.6	83.1	66.8
	Aug. 12	7.1	2.0	84.0	69.0
<u>Marsh Shores</u>					
Cadham	July 3	7.2	2.0	80.7	70.6
BW	July 13	7.6	1.5	66.5	31.1
BE	July 21	7.7	7.9	82.0	64.3
Other	July 16	7.9	7.7	50.6	23.3
<u>Borrow Pits</u>					
1	June 24	7.8	3.0	22.4	4.9
2	June 24	7.7	8.0	23.3	3.7
3	June 24	7.6	4.4	27.7	5.2
4	June 24	7.5	5.3	26.3	7.6
5	June 24	7.8	3.0	29.2	6.5
6	June 24	7.1	3.3	40.6	11.3
7	July 28	8.0	8.7	15.7	1.2

*Mean of 3 replicates

have limited plant growth. In the pits, heavy clay subsoil is exposed when the top soil layers, with the organic material, are scraped off for construction. Further analysis of the moisture and organic content data show these two parameters to be highly correlated (R = .99) and significant at the 1% level of rejection (Figure 6), confirming that soils with a high organic content are capable of holding more moisture than soils with less organic matter.

The soil samples collected along the 25 m transect at CCW gave pH values ranging from 7.4 to 8 and conductivities from 3.5 to 21 mmhos cm^{-2} (Figure 7). The variation in pH and conductivity is not correlated. Conductivities tend to be higher in the mid section of the transect than at either end, indicating a concentration of soluble salts in the central depression, possibly due to movement of soil water to the center of the basin. The range of pH and conductivity found in this one site shows how variable these parameters can be. Recent precipitation and microtopography have marked effects (Walker, 1965).

No chemical analysis was performed on soil samples. Results of cation and anion analysis for soils collected throughout the Delta Marsh by Walker (1965) were so variable they were not included within the body of her thesis. It did not seem worthwhile to repeat this analysis when the results had already proved to be non-significant.

Analyses indicated pH is generally higher and conductivity lower for marsh water than for the soil (Table VII). No trends are apparent in the data. The highest pH (9.2) was from water reflooding the Horseshoe Area after summer drawdown.

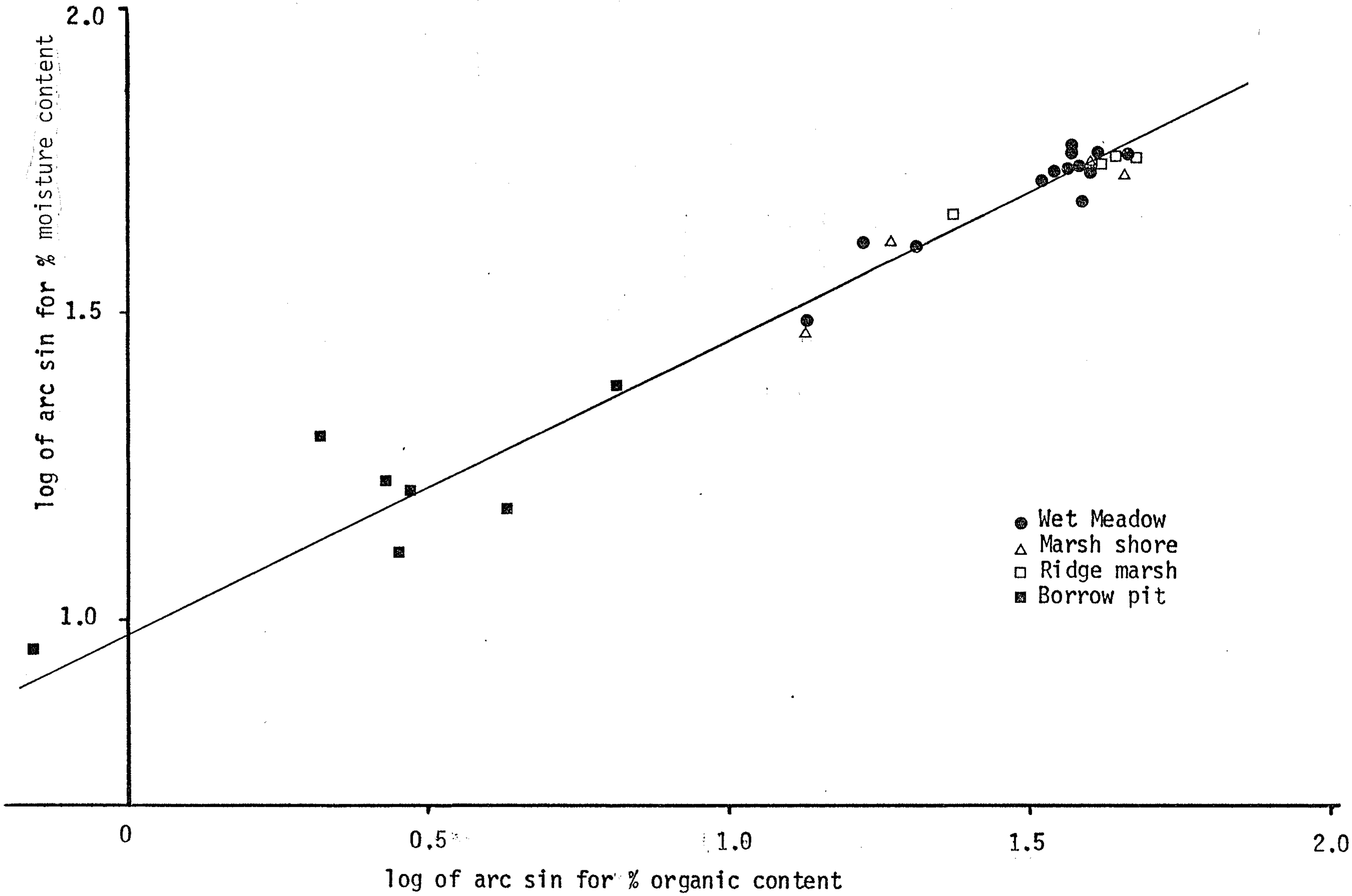


FIGURE 6: Graph of log of arc sin for % moisture content versus log of arc sin for % organic content of Delta soils, 1975.

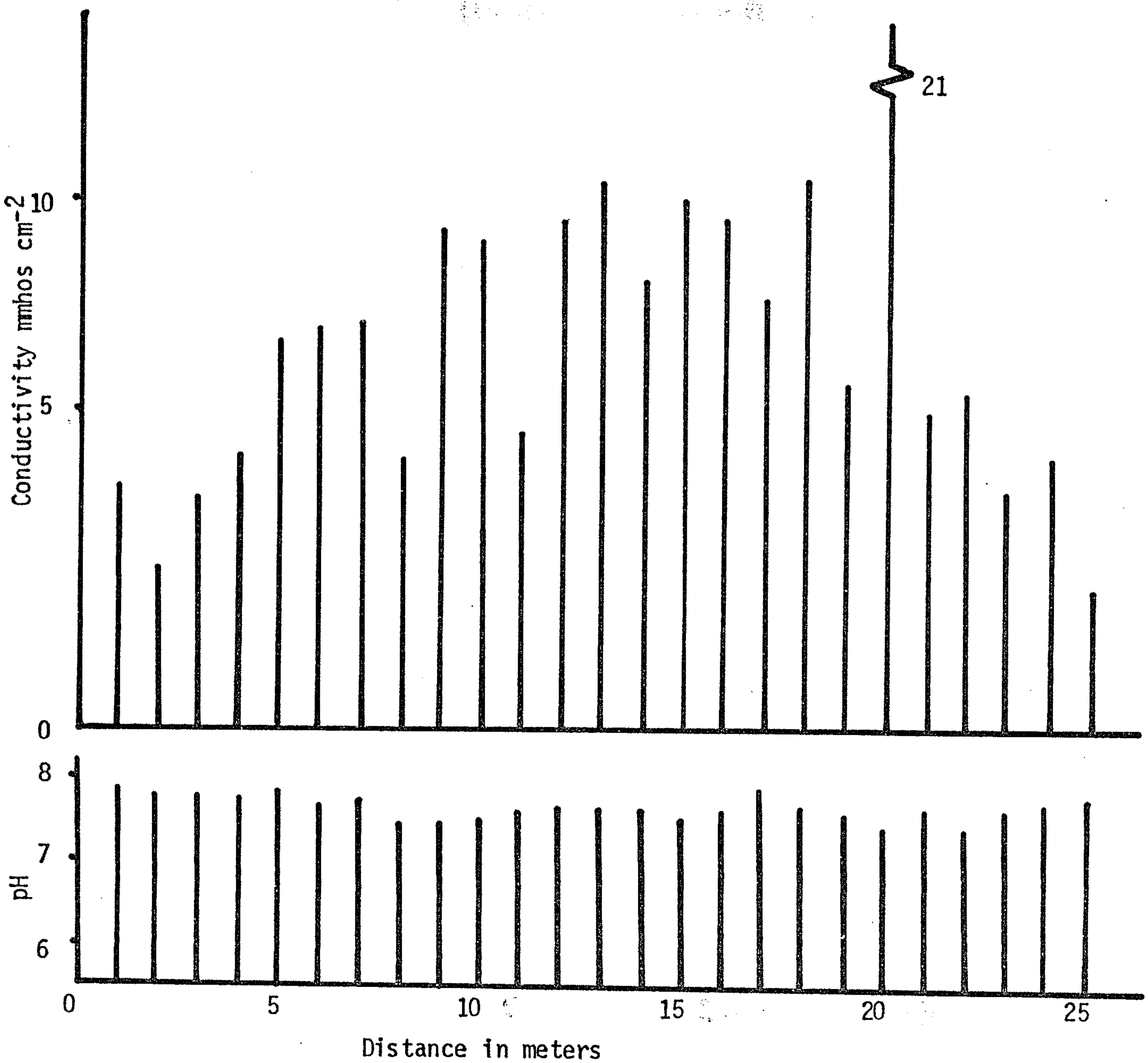


FIGURE 7: pH and conductivity of soil samples along the 25 m transect at CCW, August 14, 1975.

TABLE VII: pH and conductivity of water samples from bays and marshes at Delta, 1975.

	Date	pH*	Conductivity mmhos cm^{-2}
Wet Meadows			
Horseshoe	June 2	8.2	3.8
	July 11	8.1	5.7
	Aug. 12	9.2	5.4
CCW	July 3	8.1	5.5
Others 1	June 4	7.9	1.9
	June 24	8.2	2.0
2	June 7	8.0	1.9
3	June 24	8.2	4.9
4	June 24	8.2	7.7
Ridge Marsh			
RPE	July 3	7.9	4.7
Bays			
Cadham	June 9	8.6	2.0
	July 3	8.4	2.5
BW	July 13	8.5	2.6
Other	June 5	7.8	2.4
Borrow Pits			
1	June 6	8.4	1.2
2	June 24	8.6	1.8
3	June 24	8.8	0.9

*Mean of 3 replicates

5.2 Chenopodium rubrum Habitats

5.2.1 Floristic composition

Results of the September 1975 sampling reveal that the six species common to the three major habitats studied are Chenopodium rubrum, Atriplex patula, Aster brachyactis, Phragmites communis, Sonchus arvensis and Lycopus asper (Table VIII). The Ridge Marshes have the greatest species diversity (2 species), nine of which occur only in these sites; Galium trifidum, Scirpus fluviatilis, Rorippa islandica, Bidens cernua, Epilobium glandulosum, Mentha arvensis, Polygonum coccineum, Fragaria virginiana, Teucrium occidentale. The assortment of woody seedlings found were lumped together as one species. These areas are within the beach ridge complex, are underlain with sand and have a tendency toward being less alkaline than the rest of the marsh (Table VI). This leads to colonization from a wide range of wet ground species.

The Wet Meadows have only one species not found elsewhere in sampling, Cicuta maculata. The Marsh Shores have five different species; Scirpus validus, Senecio congestus, Impatiens capensis, Agropyron repens and Humulus lupulus. The last three species probably invaded from drier ground to the south.

Borrow pits are now conspicuous in marsh areas adjacent to the roads. Table IX lists species found in two borrow pits investigated in 1973. The five species not recorded for natural marsh sites are Salicornia rubra, Beckmannia syzigachne, Eleocharis palustris, Melilotus alba, and Puccinellia nuttalliana. These hardy colonizers are able to survive in the heavy clay that characterizes borrow pits. The first and last species are also indicative of saline conditions.

TABLE VIII: Percent frequency of species recorded in quadrats sampled in six sites in the Delta Marsh, September, 1975.

MARSH TYPE	RIDGE MARSHES		WET MEADOWS		MARSH SHORES	
STUDY AREA	RPE	RPW	AKINS	CCW	BE	BW
SPECIES+						
GROUP I*						
Galium trifidum	90.5	73.8				
Scirpus fluviatilis	77.9	63.3				
Phragmites communis	71.6	54.2	12.0		20.0	70.0
Rorippa islandica	25.8	47.6				
Typha latifolia	44.2	8.5	1.0		50.0	
Bidens cernua	22.6	22.4				
Epilobium glandulosum	41.1	1.0				
Mentha arvensis	33.7	1.0				
Stachys palustris	11.6	6.6	15.0			
Polygonum coccineum		13.8				
Cirsium arvense	3.2	7.6	1.0			
Woody seedlings	2.1	7.6				
Rumex maritimus	2.1	7.1	3.0			
Fragaria virginiana	5.3	3.3				
Scirpus acutus	5.3	2.3	1.0			
Ranunculus spp.	2.1	3.3	4.0			5.0
Sium suave	3.7	1.4	1.0			
Teucrium occidentale	0.4	0.4				
GROUP II**						
Scolochloa festucacea		5.2	48.0	20.0		
Scirpus paludosus		10.0	20.0	20.0		
Sonchus arvensis	6.8	3.8	18.0	5.0	25.0	45.0
Suaeda depressa	0.5		4.0	10.0		
Cicuta maculata			2.0			
GROUP III***						
Aster brachyactis	6.3		25.0	25.0	100.0	65.0
Atriplex patula	50.5	16.6	48.0	77.5	65.0	95.0
Chenopodium rubrum	61.6	78.1	50.0	35.0	85.0	65.0
Urtica dioica	5.3	1.0			15.0	90.0
Hordeum jubatum				22.5	30.0	40.0
Scirpus validus					10.0	40.0
Senecio congestus					25.0	15.0
Lycopus asper	23.2	0.4	7.0		5.0	25.0
Impatiens capensis						5.0
Agropyron repens						5.0
Humulus lupulus						5.0
Total number of species	24	24	17	8	12	14
Number of quadrats (625 cm^2) sampled	190	210	100	40	20	20

+ Within each group species are listed in order of frequency.
* Species occurring with the highest frequency in Ridge Marshes.
** Species occurring with the highest frequency in Wet Meadows.
*** Species occurring with the highest frequency on Marsh Shores.

TABLE IX: Species from Delta Borrow Pits investigated in 1973 listed in decreasing order of frequency.

Chenopodium rubrum
Hordeum jubatum
Atriplex patula
Salicornia rubra
Aster brachyactis
Senecio congestus
Rumex maritimus
Ranunculus cymbalaria
Beckmannia syzigachne
Eleocharis palustris
Melilotus alba
Puccinellia nuttalliana
Sonchus arvensis
Typha latifolia
Scolochloa festucacea

5.2.2 Marsh Shores

Several years of high water will kill the perennial marsh vegetation. When the water recedes colonization of the denuded areas proceeds as described by Walker (1965). Although extensive areas devoid of vegetation were not found during the course of this study, several marsh shores of limited extent were located and investigated. These shores are partially created and maintained at an early stage of succession by wave action during storms. This process was observed at one of the sites, the north shore of Cadham Bay, which was destroyed by waves uprooting existing vegetation and piling debris over everything.

Data from harvests undertaken on the marsh sites is presented in Table X. Species with the highest frequency are listed first. The discussion focuses on the two Bluebill sites as there were two harvests from each of these. A seasonal aspect is noted in the vegetation; there are 21 species present in July, but only 15 in September. This was due to the disappearance of some of the less common species which presumably were not well suited to this particular environment and did not survive to maturity. Some ephemerals, eg. R. sceleratus, habitually complete their life cycle early in the season (Walker, 1965).

Data for the most frequently encountered species from the Bluebill sites is given in Figure 8. Large plants of Senecio congestus formed the majority of the above ground biomass in July, 1975, but in September this species occurred only as a few small rosettes, thus leaving a reduced population to grow in 1976. The rosettes developed away from the main body of existing vegetation and closer to the water, beginning the colonization of a new zone of mud.

TABLE X: Mean number of plants and above ground dry weight per quadrat and percent frequency for species from three Delta Marsh Shores, 1975.

Study Area	CADHAM			BLUEBILL WEST			BLUEBILL EAST			BLUEBILL EAST			BLUEBILL WEST		
Date of Sampling	June 13			July 13			July 21			September 4			September 9		
Number of quadrats ($625\ cm^2$) sampled	20			20			20			20			20		
SPECIES*	Mean number of Plants	Mean dry weight (gm)	% Frequency	Mean number of Plants	Mean dry weight (gm)	% Frequency	Mean number of Plants	Mean dry weight (gm)	% Frequency	Mean number of Plants	Mean dry weight (gm)	% Frequency	Mean number of Plants	Mean dry weight (gm)	% Frequency
Aster brachyactis	2.8	0.73	75	6.05	1.51	80	44.4	9.5	100	17.7	13.59	100	2.2	1.51	65
Atriplex patula	34.9	1.38	85	56.7	1.15	85	5.8	4.34	85	1.2	3.45	65	7.25	12.28	95
Senecio congestus	9.4	13.65	80	3.6	16.27	75	6.5	9.43	60	0.8	0.59	25	0.2	0.03	15
Sonchus arvensis	3.3	1.50	60	1.6	2.71	55	1.0	0.09	70	0.25	0.19	25	0.7	2.46	45
Hordeum jubatum	5.7	1.21	40	9.9	2.24	65	2.1	0.04	55	1.5	0.06	30	1.95	0.13	40
Urtica dioica	0.95	0.07	20	5.75	0.08	50	35.2	1.21	60	0.3	0.13	15	6.95	2.90	90
Chenopodium rubrum				0.25	tr	20	7.25	5.67	75	4.2	7.48	90	1.45	1.03	65
Phragmites communis	0.55	1.8	30	1.2	6.03	50	1.1	7.66	25	1.4	12.15	20	4.2	13.83	70
Lycopus asper	1.3	0.38	40	5	2.32	45	0.45	0.27	15	0.05	tr	5	0.4	0.08	25
Ranunculus sceleratus	1.15	0.67	50				0.65	0.03	30						
Rumex maritimus	3.9	0.82	35	0.2	tr	10	0.25	0.03	25						
Scolochloa festucacea	0.9	1.31	35												
Typha latifolia	0.1	3.15	10	0.1	0.24	5	0.3	3.86	15	1.0	15.36	50			
Scirpus validus				1.4	4.22	30				0.35	1.38	10	1.4	3.55	40
Impatiens capensis				0.15	0.04	15	0.1	0.65	10				.05	.07	5
Scirpus paludosus	0.15	0.22	15							0.6	1.45	20			
Sonchus asper				0.65	0.25	10	0.05	tr	5						

TABLE X - cont'd.

Study Area	CADHAM			BLUEBILL WEST			BLUEBILL EAST			BLUEBILL EAST			BLUEBILL WEST		
Date of Sampling	June 13			July 13			July 21			September 4			September 9		
Number of quadrats ($625\ cm^2$) sampled	20			20			20			20			20		
SPECIES*	Mean number of Plants	Mean dry weight (gm)	% Frequency	Mean number of Plants	Mean dry weight (gm)	% Frequency	Mean number of Plants	Mean dry weight (gm)	% Frequency	Mean number of Plants	Mean dry weight (gm)	% Frequency	Mean number of Plants	Mean dry weight (gm)	% Frequency
Stachys palustris	0.05	.02	5				0.15	tr	10						
Ranunculus cymbalaria				0.15	tr	10							0.05	tr	5
Scirpus fluviatilis				0.05	0.02	5	1.05	0.04	5						
Cirsium arvense	0.05	0.01	5												
Scirpus acutus	0.01	0.05	5												
Carex atherodes				0.1	0.14										
Amaranthus retroflexus							0.05	tr	5						
Teucrium occidentale							0.05	0.07	5						
Humulus lupulus													0.05	0.09	5
Mean biomass/quadrat (gm)		26.96			37.30			48.57			52.32			35.36	
Mean number of species/ quadrat		5.9			6.15			6.55			4.5			5.7	
Total number of species		16			17			19			12			15	

*Species are listed in decreasing order of frequency.

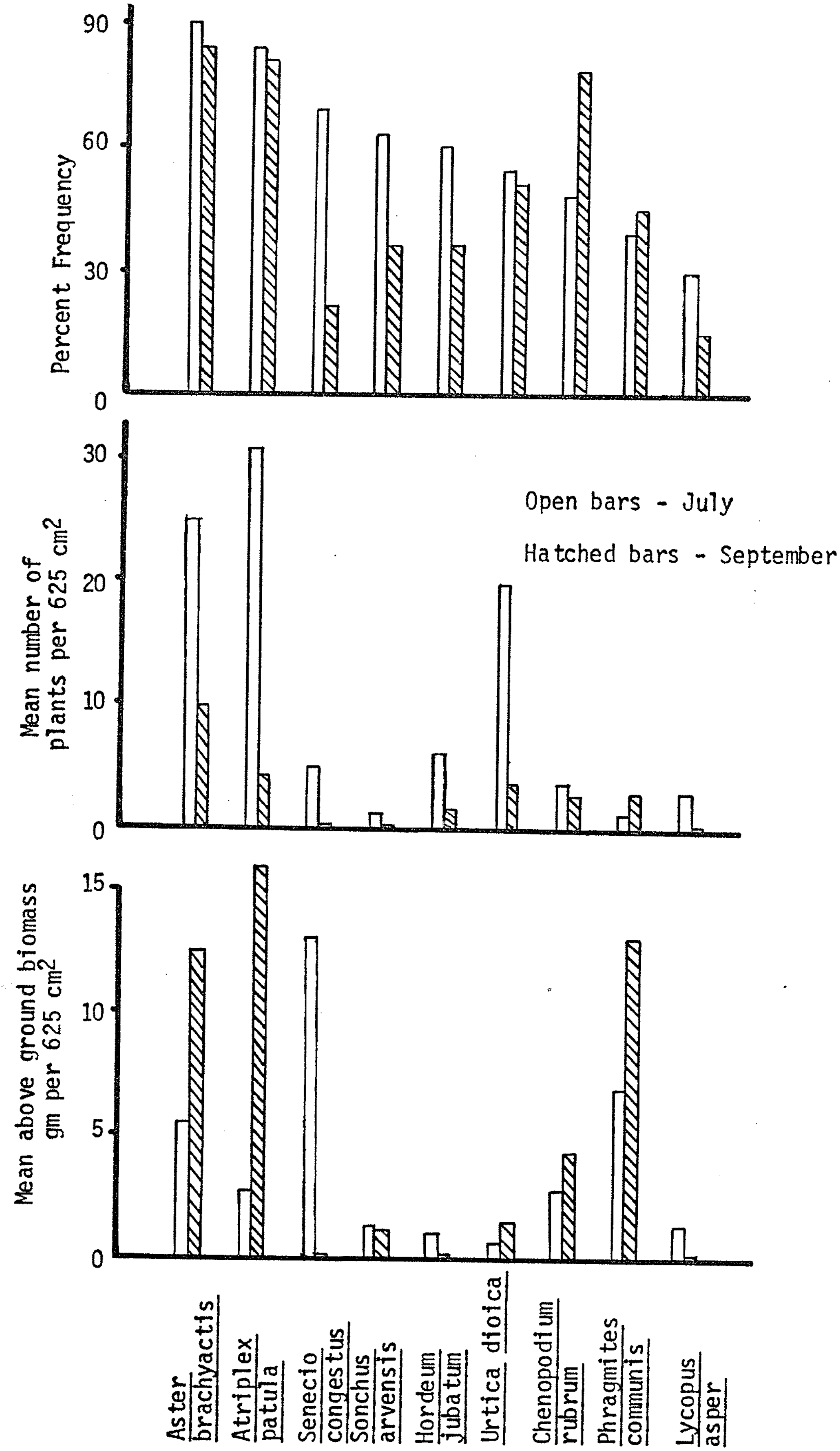


FIGURE 8: Change in percent frequency, number of plants and above ground biomass from July to September (1975) for the nine most frequent species of marsh shores.

Aster brachyactis and *Atriplex patula* were the most frequent species at both sampling times. There were large numbers of small plants in July, maturing to a few robust specimens by September. These are summer annuals which germinate in the early spring, grow through to flower and fruit in late summer. *C. rubrum* shows a similar pattern to that of *A. brachyactis* and *A. patula*, but it germinates three to four weeks later. Its growth was more severely hampered by *S. congestus* which was reaching its maximum height and flowering profusely, reducing the vigor of *C. rubrum* as compared with *A. brachyactis* and *A. patula*.

Four other species, *Sonchus arvensis*, *Hordeum jubatum*, *Urtica dioica* and *Lycopus asper* occurred with high frequencies, but were not as important on these shores as the previously mentioned plants. They declined in frequency and number from July to September and all but *U. dioica* were also reduced in biomass. The environmental conditions for these species to flourish were suboptimal. The only species which showed an increase in all three variables was *Phragmites communis*. This emergent perennial continued to produce new shoots throughout the summer as it established itself on the shores. Similar behavior was exhibited by *Typha latifolia* and *Scirpus validus*.

5.2.3 *Senecio congestus*

S. congestus can become locally abundant when sufficient seed is available on a mud flat (Harris and Marshall, 1963; Walker, 1965). It is a winter annual - plants germinate in the late summer of one year, over-winter in rosette form to elongate and flower the following spring. In August of 1974, water levels were relatively high, limiting muds available for germination of S. congestus, and thus reducing the number of populations ready to flower in 1975. The three marsh shores that supported dense zones of S. congestus were conspicuous exceptions.

On June 13, at BE, the robust plants (mean ht of 115 cm) were flowering profusely (Table XI). A new rosette population was already established (mean height of 14 cm). In July plants were reduced in height (61 cm) and flowering was nearing completion. Virtually no C. rubrum was found with the S. congestus. Presumably shading by the latter prevented germination.

At Cadham, in July, plants were a mean height of 60 cm and had 16 flower heads. Those at BW were 101 cm with 45 flower heads. By this time the plants that had not flowered were beginning to rot at the top. These were smaller plants suffering the effects of being shaded by taller individuals.

The September samples revealed that the early summer rosette S. congestus population was flowering and another population of rosettes was developing. Plants at BE were larger than those at BW (mean heights of 95 cm and 65 cm respectively) and produced more flower heads (239 v.s. 130). Fall rosettes were slightly larger at BE with a mean height of 36 cm and 34 cm for BW.

As previously mentioned S. congestus usually functions as a winter annual at these latitudes. In northern environments the short growing season forces it to be a perennial. This is the first record, however, of it being a summer annual. The summer annual pattern was not reported by Walker (1965) for Delta populations or by Harris and Marshall (1963) in Minnesota.

TABLE XI: Mean height (cm) and number of flower heads of *Senecio congestus* on three Marsh Shores at Delta, 1975.

	Spring Flowering		Summer Annuals		Fall Rosettes
	Height	Number of Heads	Height	Number of Heads	Height
Bluebill East					
June 13	115	fl.*	14	vegetative	-
July 21	61	26	-	-	-
September 4	-	-	95	239	36
Bluebill West					
July 13	101	45	-	-	-
September 9	-	-	65	130	34
Cadham Bay					
July 3	60	16	-	-	-

*Plants were flowering but heads were not counted.

Investigations carried out in 1973 and 1974 showed *S. congestus* is capable of plastic response to excessive water levels. In the spring of 1973 *S. congestus* rosettes at the water's edge grew to an average height of 55 cm with mature plants becoming much branched (Figure 9). The peak of growth was associated with flowering and fruiting which began towards the end of May. Flower production was abundant. Water levels dropped through the summer and in the fall of 1973 new rosettes developed further down the shore.

In the spring of 1974 flood waters covered the plants to a depth of 1 m. They elongated rapidly, but flowering was delayed until the water levels had fallen and inflorescences had appeared above it (Figure 10). The average height of the *S. congestus* was greater in 1974 than in 1973, but plants were unbranched and fruit production reduced, as only the terminal inflorescences flowered. Elongated plants were susceptible to wave action and many individuals were uprooted and found floating on the water. Plants not able to reach the water surface did not flower and rotted as did the rest of the plants once fruiting was complete.

5.3 Phenology and Growth of *Chenopodium rubrum*

5.3.1 Seedling survival

Initial counts made on 100 quadrats of seedlings at RPW ranged from 1 to 183 plants, but on recounting 17 days later, the range was 0 to 18 plants for the 25 cm^2 quadrats. Figure 11 shows these data converted to density per cm^2. Mean survival is .02 plants per cm^2 or 27%. Survival was high when initial seedling density was low, decreasing to low survival with high initial density (Figure 12). Fourteen quadrats were lost due to trampling by deer.

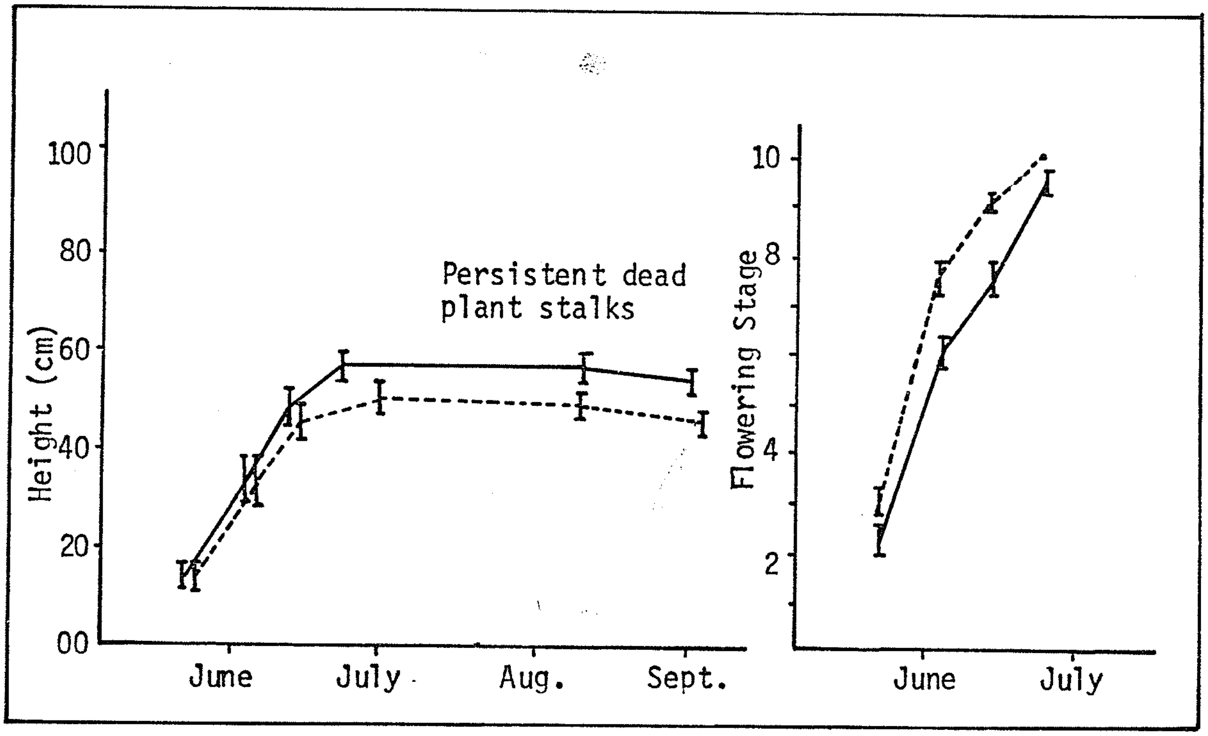


FIGURE 9: Height and flowering stage of Senecio congestus in two sites, 1973. Flowering stage was recorded on a scale from 0 to 10, where plants are vegetative at 0, flowering begins at 5 and fruiting at 9. Bars show standard error of the mean.

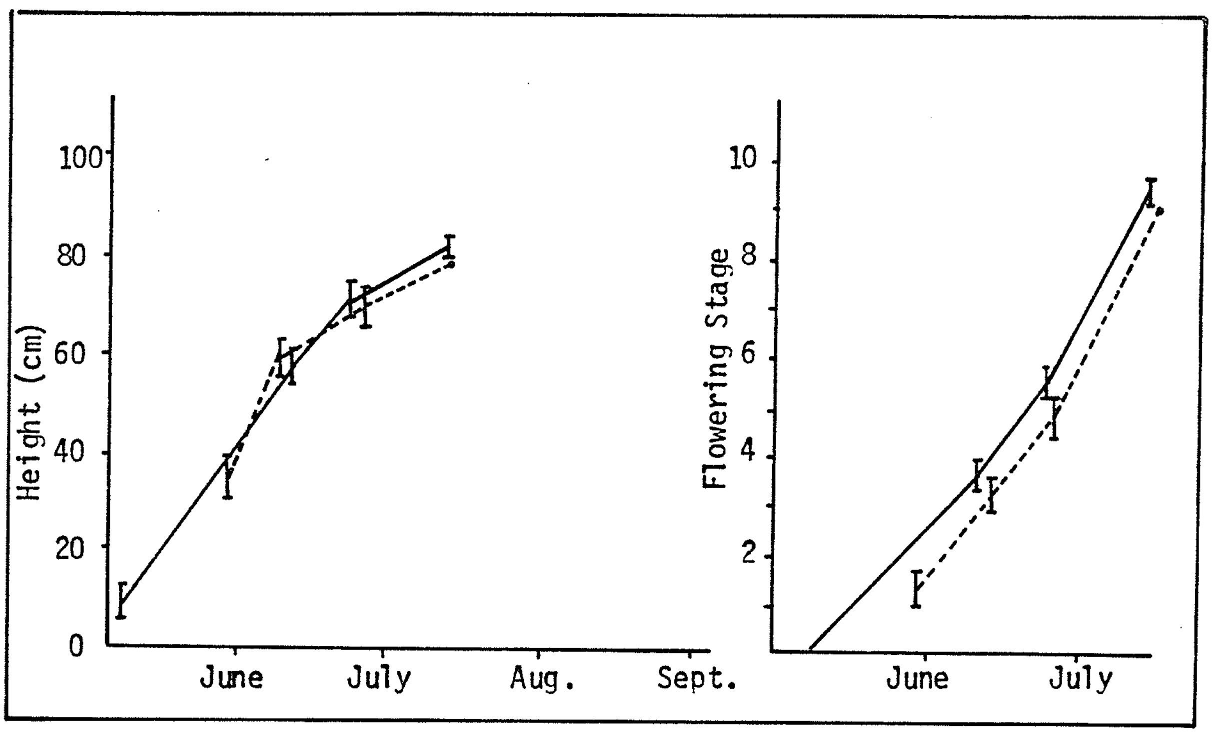


FIGURE 10: Height and flowering stage of Senecio congestus in two sites, 1974. Notes as above.

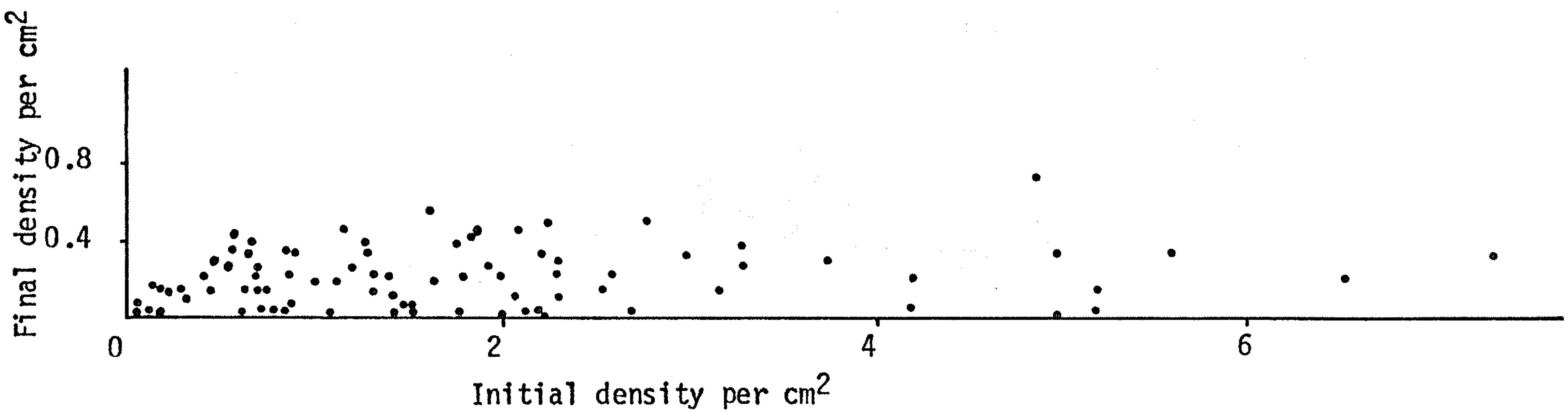


FIGURE 11: Density of <u>Chenopodium rubrum</u> seedlings in initial (August 5) and final (August 22) count in 1975.

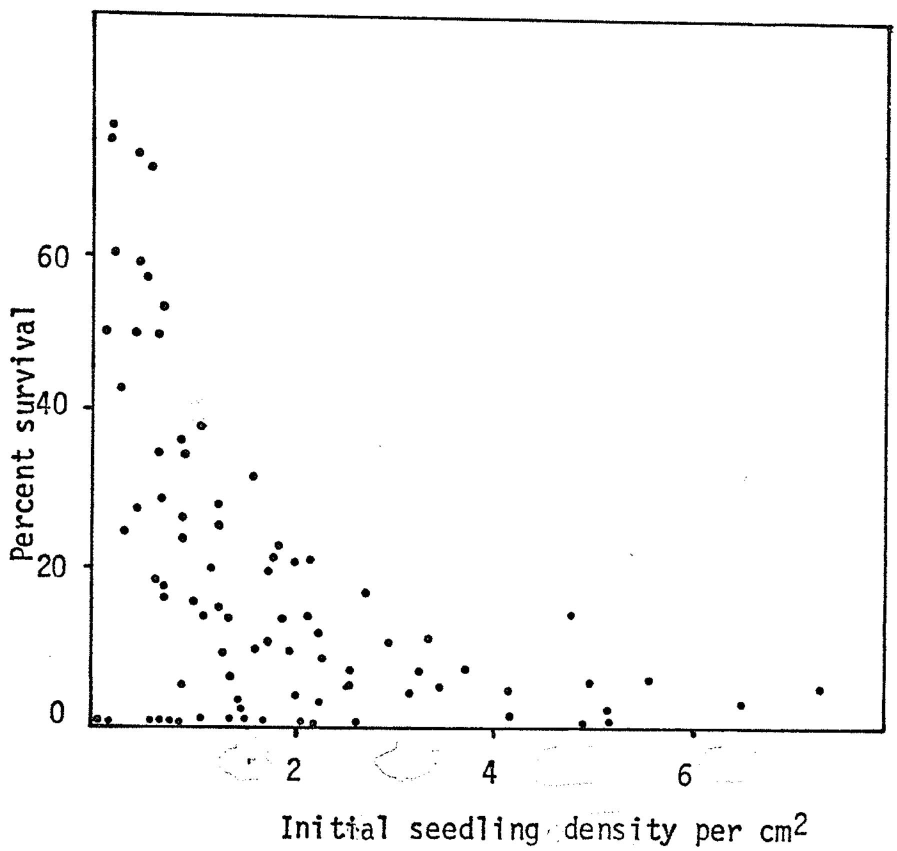


FIGURE 12: Percent survival of Chenopodium rubrum seedlings from August 5 to August 22, 1975.

The excessive mortality was presumably the result of waterlogged soil combined with high seedling density. Many seedlings gradually lost their leaves until only a bare stem remained, which eventually rotted. None of the quadrats was in a position which experienced flooding, but seedlings in adjacent depressions were covered by rain and died. Upon redrying, C. rubrum failed to become re-established in any of these low areas. It is likely that all available seed had already germinated.

5.3.2 Habit and Phenology

The measurements of plant height, horizontal diameter, and leaf number for three time periods are plotted in Figure 13. It is interesting to note that the dike populations, H and F, are quite distinct from the others for all characters. They show little increase in height through August, having completed most of their vegetative growth earlier in the summer. The other populations show approximately equal growth, except for G which has a late August acceleration.

Horizontal diameter shows little change or a slight decrease over time. This would tend to suggest that the branching pattern is established early with later growth being primarly elongation. The decreases were due to loss of large leaves on the lower parts of the plants.

The pattern for leaf number is somewhat erratic, although all populations show an increase. In the field there is a gradual loss of lower leaves, particularly under crowded and/or waterlogged conditions, and a rapid increase in leaf formation towards the apex as the inflorescence elongates. The determination of leaf number is subject to some

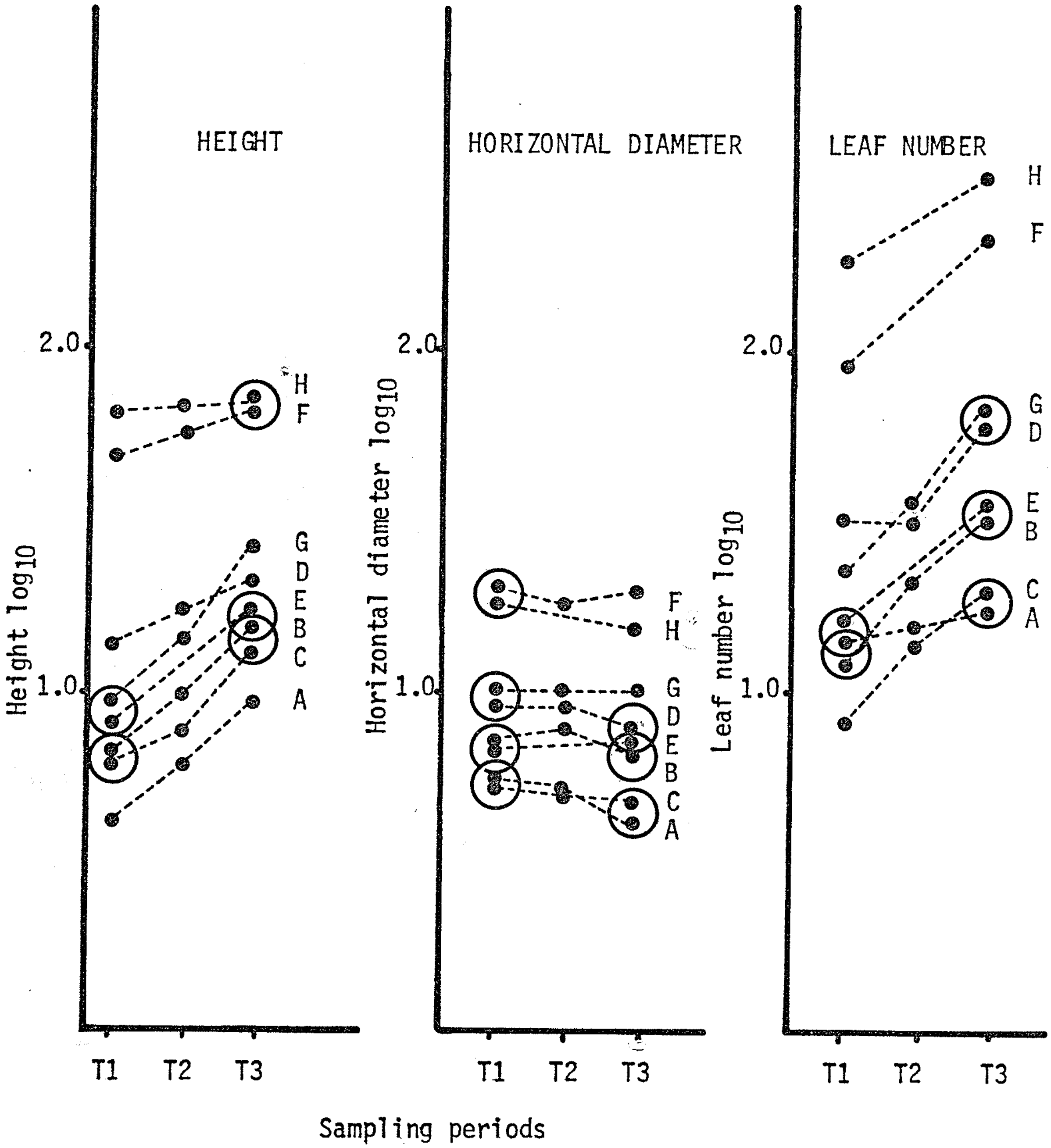


FIGURE 13: Means ($\log_{10}$ transformation) for height, horizontal diameter and leaf number of Chenopodium rubrum at eight sites for three sampling periods in 1975.

T1 is early August, T2 mid August, and T3 is September 1. Populations within the same circle are not significantly different as determined by the Student-Newman-Keuls Test.

Habitats where samples located:
H, F dikes
G, E ridge marsh
A, B, C, D wet meadow

error as there is no clear point differentiating the leaves from the leafy bracts of the inflorescence. The result is that with small plants, having small leaves, the tendency is to confuse some of the bracts and leaves.

Analysis of variance performed on the measurements of plant height, horizontal diameter, and leaf number at T_1 (early August, 1975) and T_3 (September 1, 1975) for the marked Chenopodium resulted in F tests that were all significant at the 99% probability level, indicating that not all the means of these characters are equal (Table XII). The results of the comparisons of all means by the Student-Newman-Keuls test are plotted with the data in Figure 13.

To examine the differences between populations in more detail the untransformed data at T_3 are plotted in Figure 14. The most robust plants were those growing along dike edges where the soil had been completely turned over, greatly reducing competition from other plants. These areas were available for colonization early and subsequently were well drained.

The three populations F, G and E were all from the same Ridge Marsh environment, but grew on different microsites. F was a dike population as noted above, while G and E grew in the marshes which had been subjected to management procedures (Table II). The reduced vigor of the E plants over those at G was the result of greater competition from Phragmites communis (Table XV) and the slightly waterlogged condition of the hollow in which they were growing. Although the West Area in general was wetter than the East, the marked plants at E were in a waterlogged depression. Soil samples from these areas (Table VI)

TABLE XII: Analysis of variance on height, diameter and leaf number for eight populations of *Chenopodium rubrum* in the Delta Marsh for two sampling periods in 1975.

SOURCE	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	F RATIO
T_1 (Early August)				
Height	7	26.14	3.73	261.26**
Error	152	2.17	0.01	
Total	159	28.31		
Diameter	7	6.82	0.97	84.26**
Error	152	1.76	0.01	
Total	159	8.58		
Leaf Number	7	29.83	4.26	142.83**
Error	152	4.5	0.03	
Total	159	34.37		
T_3 (September 1)				
Height	7	13.26	1.89	99.49**
Error	144	2.74	0.02	
Total	151	15.62		
Diameter	7	7.08	1.01	57.01**
Error	144	2.56	0.02	
Total	151	9.23		
Leaf Number	7	27.92	3.99	95.56**
Error	144	6.01	0.04	
Total	151	33.42		

** Significant at the 99% probability level.

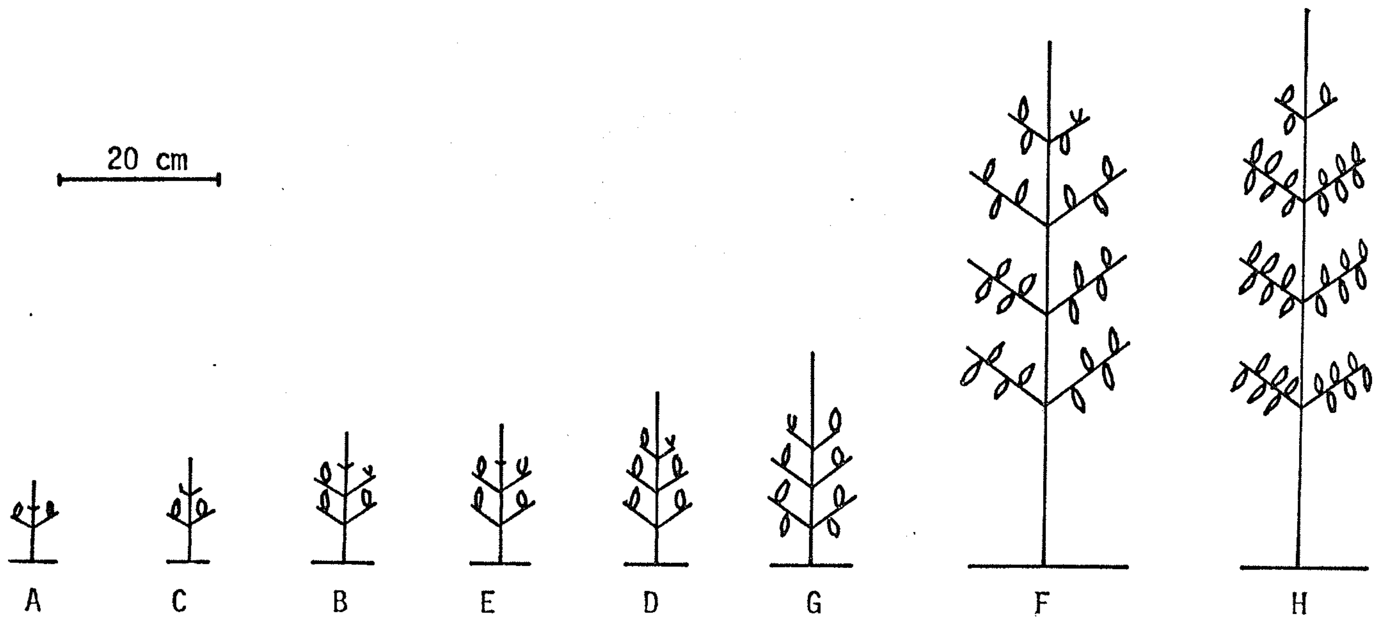


FIGURE 14: Diagramatic representation of height, diameter, leaf number and branching of Chenopodium rubrum at eight sites, September 1, 1975.

Plant sketches -height is indicated by the main axis
-horizontal diameter is shown by the horizontal line at the base of the plant
-relative branching is determined by counting the number of branches on one side of the main axis. The length of the branch is scaled to the diameter of the plant. Branching at F, for example, is 3.4.
-each leaf shown on the diagram is equivalent to 10 leaves on the original plants.

Habitats where the eight populations were located:

H, F dikes
G, E ridge marsh
A, B, C, D wet meadow

indicate a slightly lower pH than for other sites, possibly because the waters are primarily derived from incident precipitation and not drainage from any surrounding area.

Populations D and C were separated by 10 m but the C plants grew up several weeks later on soil which had been tilled. The soil at this site had a lower percentage moisture and organic matter than most of the marshy sites and for both of the parameters the values on the second date, after tilling, were lower while the conductivity reading was the highest recorded (Table VI). The A and B populations were both found in very similar openings in Scolochloa festucacea meadows. Soils showed little difference in pH, conductivity and organic content (Table VI).

The above data illustrate some of the range of variation found in the growth habit and leaves of C. rubrum in the Delta Marsh. Walker (1965) reported two growth forms. Large individuals (150 to 200 cm), growing singly, were triangular in shape, coarse, woody and much branched. Smaller plants (50 cm) were slender, unbranched and numerous.

Tall plants (over 150 cm) were observed growing on fresh silt deposits. Williams (1969) attributes phenotypic plasticity to a response to soil nutrient conditions, stating that the largest plants grow in nitrogen rich soils. But C. rubrum is a short-day plant (Cumming, 1963) thus early germinating plants have a long period for vegetative growth and have potential to become tall. Short plants (10 to 20 cm) were observed in the heavy organic deficient, clay soils of borrow pits. These plants sometimes compensate for their lack of height by spreading out horizontally.

The degree of branching in *C. rubrum* is a function of the availability of resources. Cook (1976) found that when resources are abundant, the degree of apical dominance is reduced and there is abundant growth of axillary bud primordia. *C. rubrum* growing in dense situations and in competition with other species where resources, especially light, would be limiting were unbranched. This was also the form exhibited by plants growing in waterlogged soils.

Leaf number is affected by environmental conditions. The normal late season loss of lower leaves is accentuated when *C. rubrum* individuals are crowded. Where it grows as an understory species, it is somewhat etiolated and has fewer leaves for its height than plants in full light.

Leaves are more or less lobed depending on age and habitat conditions. Early leaves are shallowly lobed as are those of plants growing under adverse conditions of fertility and moisture.

Individual leaves, as they are produced, become progressively larger through the early part of the season, then leaf size decreases as the small bracts of the inflorescence begin to appear. Leaves produced in close to optimal marsh habitats are larger than those produced on plants growing in saturated soil or in borrow pits (Table XIII, data collected in 1973). Shedding of the large lower leaves in the later parts of the growing season account for the decrease in horizontal diameter of the plants.

Leaf thickness is variable (Williams, 1969). Leaves are fleshiest in borrow pit situations. Leaves are thin and almost flaccid where overtopped by dense emergent growth. Leaf colour follows a similar trend, the leaves are green above and bright purplish-red on

TABLE XIII: Mean height and leaf dimensions (cm) for three populations of *Chenopodium rubrum* in 1973.

	Marsh		Waterlogged Shore		Borrow Pit	
	Height	Leaf Size	Height	Leaf Size	Height	Leaf Size
Mid-August	83	12.5 x 5.7	15.9	1.94 x 0.55	9.3	3.2 x 2
Mid-Sept.	111	11.5 x 4.6	19	small bract leaves only	20.2	3.6 x 1.2

margins in borrow pits, but are pale green with very little red below, when shaded.

5.4 Management

5.4.1 Assessment of the planting experiment

Chenopodium rubrum seed was planted in three areas in the East Delta Marsh and a fourth area was reserved as a control. September above ground stand crop was sampled and data obtained for number of *C. rubrum* per quadrat and their dry weight. Analysis of variance was performed on these data (Table XIV). In all the experimental areas there was no significant variation between mean *C. rubrum* number or dry weight for the treatments, but there is a significant variation in mean *C. rubrum* number and dry weight between the replicate plots. The microtopography of the sites caused variation in the results, masking the effects of the seed density treatments. Vehicle ruts, made by the marsh tractors, filled with water in the rains that began soon after planting and prevented uniform germination. It was apparent however, that residual seed was plentiful, as the control plots which had no seed applied, produced as much *C. rubrum* as the seeded plots.

Although there were more *C. rubrum* per quadrat at RPE (17.86 plants per 625 cm^2) than at RPW (9.18 plants per 625 cm^2), the above ground standing biomass of plants at RPW (2.11 gms per 625 cm^2) was greater than at RPE (1.52 gm per 625 cm^2) (Table XV). The *C. rubrum* at RPW made up 32.6% of the total biomass, but only 3.7% at RPE. In spite of patchy flooding, *C. rubrum* was more successful at RPW than at RPE.

TABLE XIV: Analysis of variance on number and above ground biomass of seeded *Chenopodium rubrum* from quadrats (625 cm^2) clipped September, 1975.

SOURCE	RPE d.f.	RPE S.S.	RPE M.S.	RPE F	RPW d.f.	RPW S.S.	RPW M.S.	RPW F	AKINS d.f.	AKINS S.S.	AKINS M.S.	AKINS F
Number of *C. rubrum*												
Among Treatments	4	24316.7	3079.2	1.74n.s.	6	2896.3	482.72	1.16n.s.	3	328.78	109.59	0.59n.s.
Among Plots	14	48834.9	3488.2	2.06*	14	5810.9	415.06	2.45**	6	1121.41	186.9	3.72**
Within Plots (Error)	171	289994.8	1695.9		189	31962.3	169.11		90	4517.4	50.19	
Total	189	363146.4			209	40669.5			99	5967.59		
Biomass *C. rubrum*												
Among Treatments	4	36.29	9.07	0.70n.s.	6	195.14	32.52	1.16n.s.	3	16.17	5.39	0.87n.s.
Among Plots	14	181.64	12.97	4.03**	14	391.00	27.93	4.67**	6	40.52	6.75	4.35**
Within Plots (Error)	171	551.46	3.22		189	1130.39	5.98		90	139.56	1.55	
Total	189	769.39			209	1716.18			99	196.25		

*F test significant at 5% level.

**F test significant at 1% level.

TABLE XV: Mean number of plants and mean above ground oven dry biomass (gm) per quadrat (625 cm^2) for Chenopodium rubrum from four managed areas in the Delta Marsh, September 1975.

SITE TYPE	RIDGE MARSH				WET MEADOW			
Area	RPE		RPW		Akins		CCW	
Number of Quadrats clipped	190		210		100		40	
QUADRAT MEANS	Number of Plants	Biomass	Number of Plants	Biomass	Number of Plants	Biomass	Number of Plants	Biomass
Chenopodium rubrum	17.86	1.52	9.18	2.11	4.21	0.51	1.2	0.12
Phragmites communis	3.01	7.75	1.77	2.29	0.22	0.23	0	0
Typha latifolia	1.58	2.93	0.12	0.04	0.02	0.04	0	0
Scolochloa festucacea	0	0	0	0	3.18	0.39	0.38	0.21
MEAN TOTAL BIOMASS PER QUADRAT	26.60		6.47		3.16		3.9	
Biomass of *C. rubrum* as percent of total biomass	3.7		32.6		16.14		3.1	
Frequency of *C. rubrum*	62%		78%		50%		35%	
Empty quadrats	0		0		22%		10%	

Competition from emergent species was less at RPW than at RPE (Table XV). The number and biomass of Phragmites communis shoots wereless at RPW (1.77 plants and 2.29 gm per 625 cm^2) than at RPE (3.01 plants and 7.75 gm per 625 cm^2). The same is true for Typha latifolia; numbers and biomass were less at RPW (0.12 plants and 0.04 gm per 625 cm^2) than at RPE (1.58 plants and 2.93 gm per 625 cm^2). RPW was tilled a second time before planting the C. rubrum, but RPE was only tilled once. The importance of reducing competition from emergents to favour growth of C. rubrum is emphasized by these data.

Akins Bay and CCW showed low productivity, neither site averaging over 4 gm per 625 cm^{-2} (Table XV). Both of these sites experienced some flooding which restricted the growth of annuals. C. rubrum was a prominent component of the vegetation at Akins but at CCW Atriplex patula was more successful. The reduced growth of Scolochloa festucacea at CCW as compared with Akins probably resulted from the annually repeated tilling that this area has experienced.

The managed sites were flooded in the fall to attract migrating teal. Large flocks of green- and blue-wing teal with mallards were observed to use the CCW and Akins Bay areas in the latter part of September, but the Round Pond sites were never utilized. Possibly the heavier cover of P. communis was not attractive to the ducks.

In October, several square meters of C. rubrum, eaten down to the same level by deer, were observed. The large C. rubrum plants found along the dikes did not appear to be browsed.

5.5 Growth Chamber Studies on *Chenopodium rubrum*

5.5.1 Germination

Light intensity

After 18 days there was no significant difference in percent germination between the light intensity treatments (Figure 15). Seeds in the dark germinated at a slower rate than seeds with light. For example at Day 9 approximately 25% of the seeds in the dark had germinated, while there was 65% germination with light. *C. rubrum* is known to require light to germinate, but at low alternating temperatures this condition is removed (Cumming, 1959). The temperatures for these experiments (20°C day and 10°C night) are moderate. These moderate alternating temperatures combined with short exposures of the seeds to light while the counts were made probably explains why the seeds in the dark germinated at all.

Temperature

The fastest germination rates occurred at the higher temperatures; 94% germination after 5 days at 30°C day - 20°C night (Figure 16). There was 88% germination at a constant regime of 20°C after nine days, but Cumming (1959) found germination at temperatures less than 25°C was negligible. The alternating regimes produced differing results. Cumming (1959) found complete germination in all alternating temperatures with light. Differences in the results may be due to photoperiod and/or light quality. Cumming used 8-hour, short days and these experiments were conducted under 16-hour days. It is difficult to directly compare the data reported here with those of other workers because of the different genetic makeup of the biotypes involved.

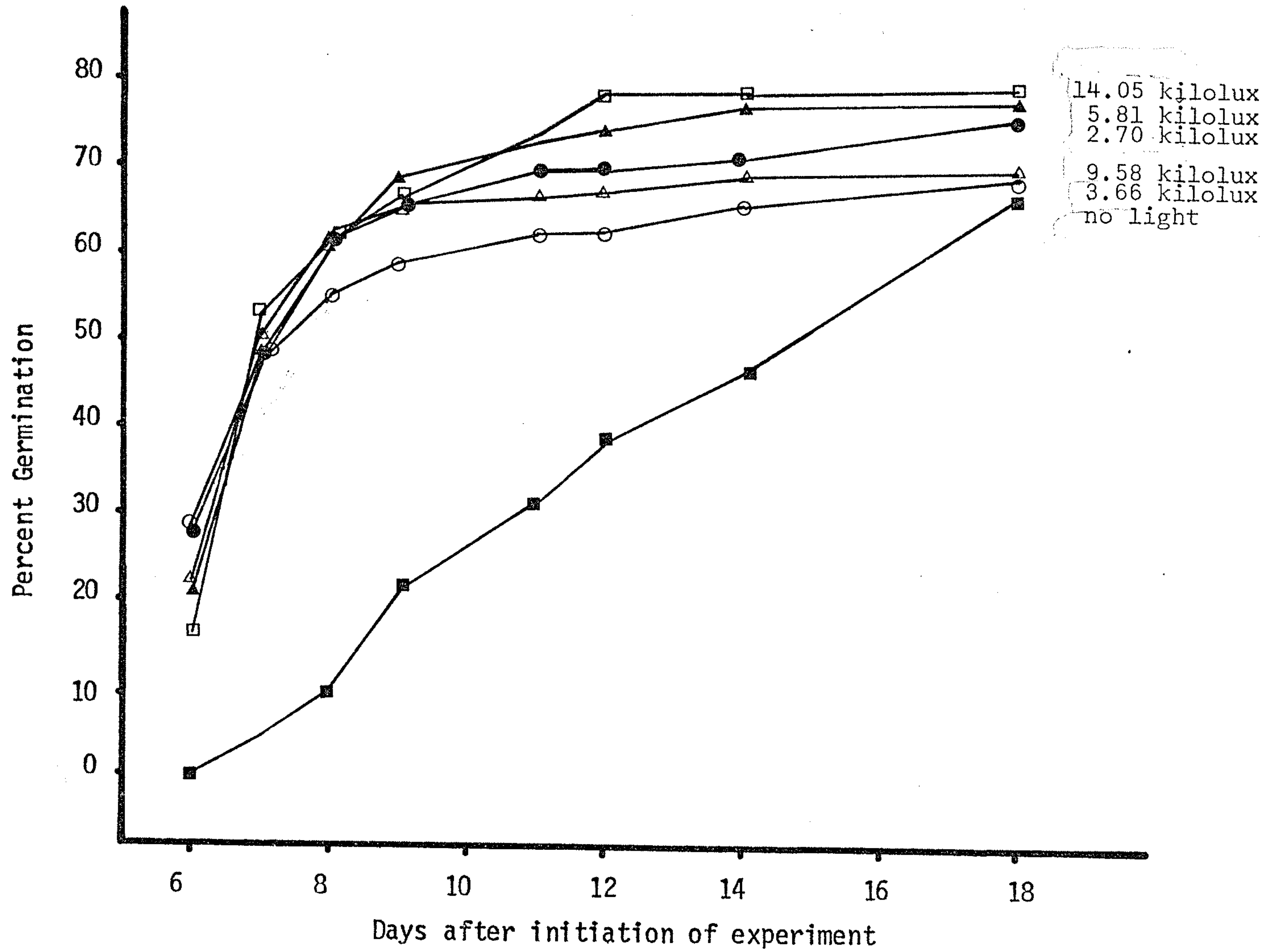


FIGURE 15: Percent germination of Chenopodium rubrum seed subjected to six light intensity treatments.

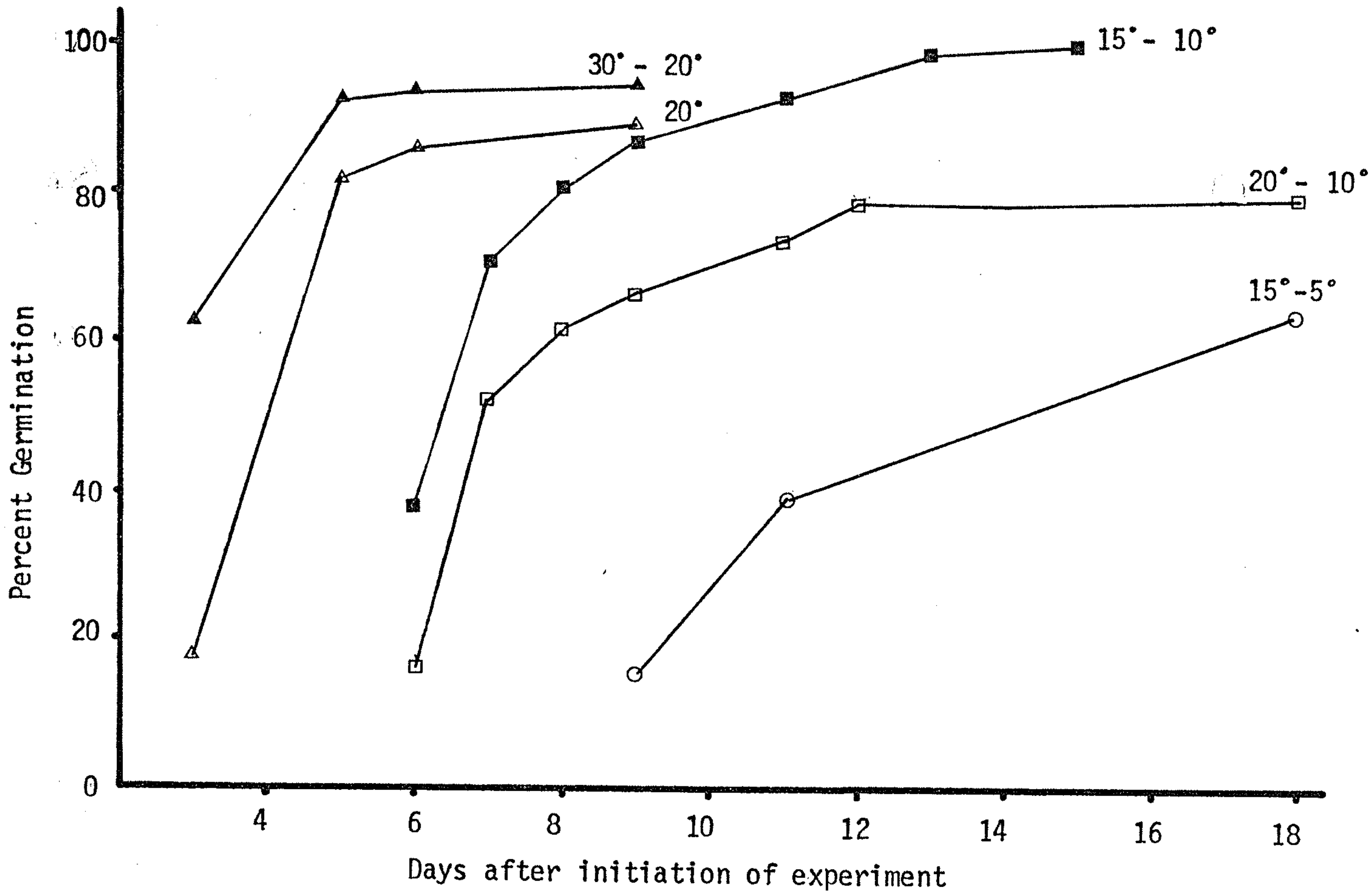


FIGURE 16: Percent germination of Chenopodium rubrum seed subjected to five temperature regimes.

Hydration - Dehydration

The control batch of seeds achieved 85% germination after 12 days of continuous moisture. There is a trend towards a decrease in germination with each drying period; 77% germinated after one drying period and 70% after two. Cumming (1963) reported that germinating seeds could suspend growth under adverse conditions and remain viable, germinating rapidly when transferred to optimum conditions.

5.5.2 Seedling response

Depth of Seedling emergence.

There was 48% emergence from seeds planted on the soil surface and 6.4% from 3 mm below the soil surface (Figure 17). Emergence from depths greater than 3 mm was nil, except in one replicate where 3 seedlings appeared from a planting depth of 10 mm. These seedlings were at the very edge of the cup where the covering of soil may have been less than the treatment prescribed. Williams (1969) reported that seedlings emerged from 0.5 to 4 cm below the soil surface. These experiments tend to indicate there is germination from only the top few millimeters and certainly not up to 4 cm.

Density

Seedling survival was highest 88% with an initial density of 0.1 plants per cm^2 decreasing to 58% where initial density was 3.6 plants per cm^2 (Figure 18). Field and laboratory data can be compared by selecting similar densities. Field survival data approximately equal to the laboratory densities of 0.1, 0.5, 1.8 and 3.6 plants per cm^2 are 43%, 36%, 8% and 5%. The

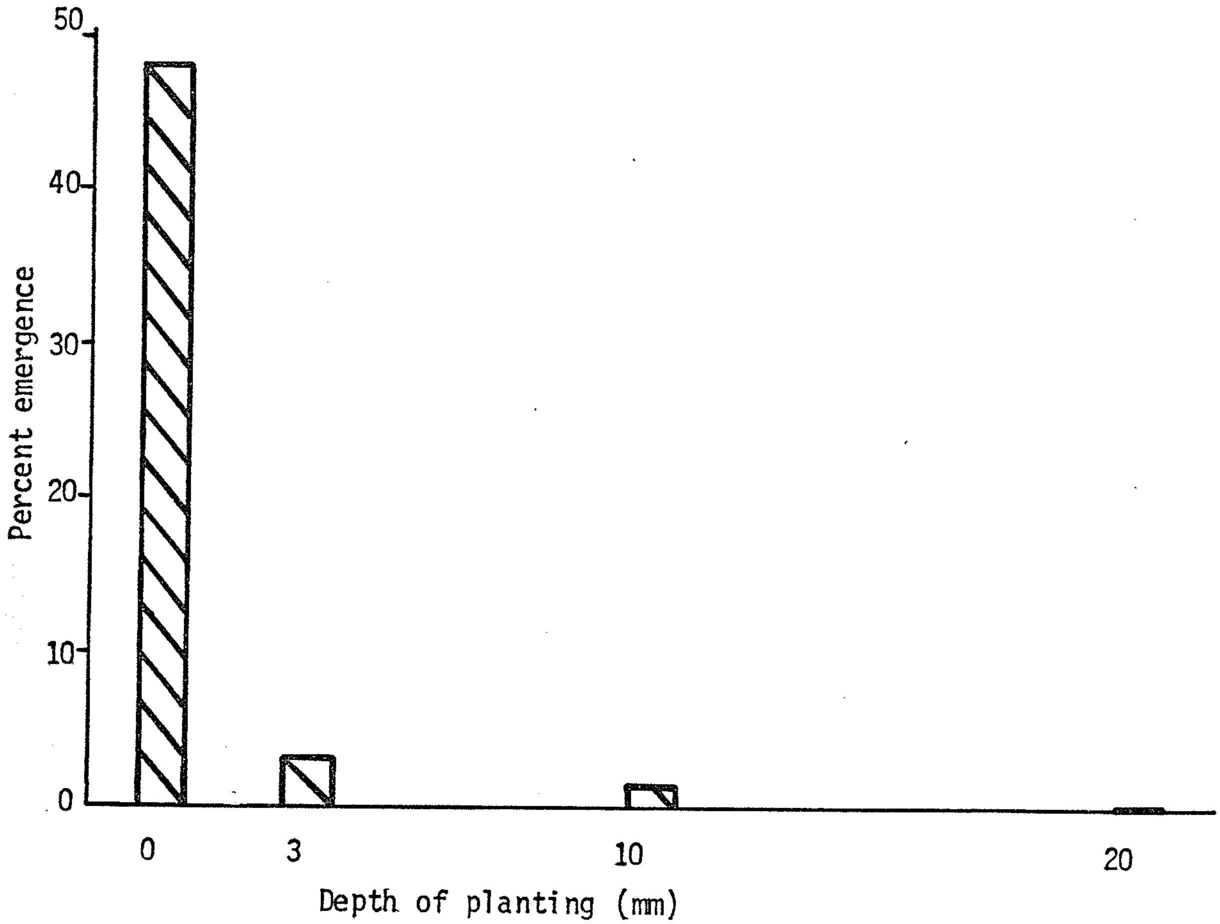


FIGURE 17: Percent emergence of <u>Chenopodium rubrum</u> seedlings from seed planted in soil at four depths.

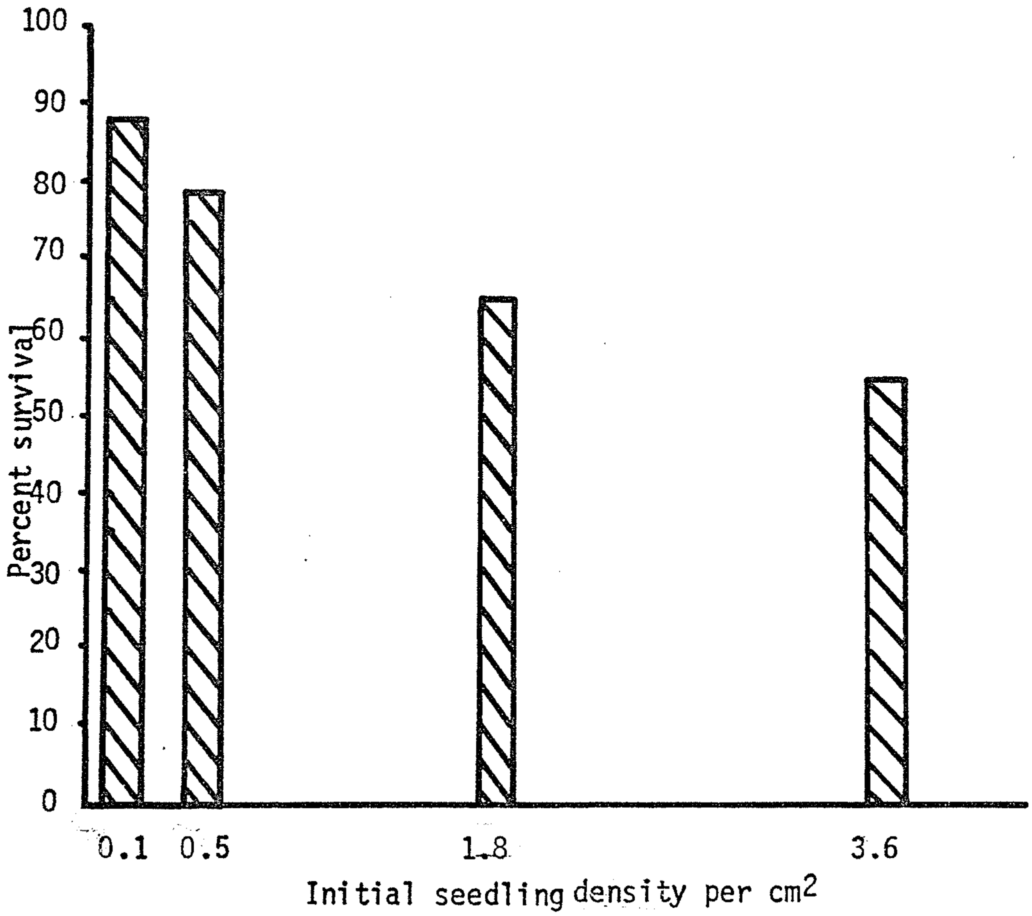


FIGURE 18: Percent survival of seedlings planted at four densities.

trend of decreasing survival with increasing density is found in both environments, but the field data show a more extreme response. Presumably the growth chambers provided more suitable growing conditions than the waterlogged soil of RPW.

Water regime

Treatment 1: After a week of flooding soils were allowed to dry. Surface water disappeared after three days and seedlings emerged by the end of the second week. The survivors (86%) had a mean height of 2.93 cm (Table XVI). These plants had 10 days less growing time than the plants in treatments 2 to 6.

Treatment 2: After the young seedlings had been flooded with 1 cm water at week 2,algae grew prolifically. The C. rubrum seedlings were easily uprooted by any disturbance. During the subsequent drawdown the algae dried out and formed a discontinuous crust over seedlings and soil. Only plants that were able to come up through the cracks in the algae crust were able to survive (6%).

Treatments 3 and 4: The young plants grew normally for three weeks before flooding. Survival was minimal with flooding of 5 cm (3%) and mean height only 1.33 cm. The 27% surviving flooding of 1 cm (mean height 1.59 cm) were able to emerge from the water.

Treatment 5: The survivors (84%) grown under the regime of moderate moisture had a mean height of 4.8 cm and were the largest and leafiest plants produced.

Treatment 6: The continuously waterlogged soil allowed only 13% survival. Although the plants attained a mean height of 3.34 cm they were less robust and had fewer leaves than the specimens of Treatment 5.

TABLE XVI: Percent survival and mean height of survivors for *Chenopodium rubrum* grown under six water regimes.

Treatment Number *	% Survival per Pot	Mean Height of Survivors (cm)
1 **	86	2.93
2 **	6	2.00
3 **	27	1.59
4 **	3	1.33
5 **	84	4.18
6 **	13	3.34

*refer to page 33 for a description of the treatments

**each treatment consists of 10 pots with 10 plants each.

The control plants (Treatment 5) and those in Treatment 1 showed the greatest percent survival, the control plants growing taller in the 10 extra days. Flooding reduced survival and growth, the effect being greatest when seedlings were completely submerged. Plants growing in saturated soil showed reduced survival and were less vigorous when compared with the control plants.

6. *Chenopodium rubrum* - ECOLOGY AND MANAGEMENT

Habitat

In North America, *C. rubrum* is a species of wet habitats, primarily newly exposed mud. In temperate regions it is characteristic of sloughs and lake margins where it appears in drought years and during seasonal drawdown (Moyle and Hotchkiss, 1945; Löve and Löve, 1954; Harris and Marshall, 1963; Walker, 1965; Dodd and Coupland, 1966; Miller, 1969; Stewart and Kantrud, 1969; Duebbert, 1969). It is a successional plant at Delta colonizing drained areas (Walker, 1965) and appearing after a disturbance such as fire (Ward, 1968). It can tolerate moderately brackish conditions (Stewart and Kantrud, 1969).

The species most commonly associated with it at Delta are *Phragmites communis*, *Sonchus arvensis*, *Lycopus asper*, *Atriplex patula* and *Aster brachyactis*. Ridge Marshes have high species diversity (24), a response to the sandy, almost neutral soils of the forested ridge complex. Marsh Shores included species invading from dry ground to the south. Borrow pit colonizers include species indicating saline conditions.

Studies of composition of Marsh Shores showed that in 1975 *Senecio congestus* was the dominant early season plant. As these robust individuals senesced, populations of annuals including *Aster brachyactis*, *Atriplex patula* and *C. rubrum* colonized and became late season dominants. New rosettes of *S. congestus* developed at this time and indications were that in 1976 the populations on these shores would be greatly reduced.

Senecio congestus appears sporadically in habitats similar to those of *C. rubrum* (Löve and Löve, 1954; Harris and Marshall, 1963; Walker, 1965; Miller, 1969; Stewart and Kantrud, 1969; Smith, 1971), although it is less tolerant of alkalinity (Stewart and Kantrud, 1969). It functions as a winter annual - seed germinates in the late summer of one year, rosettes over winter and plants elongate and flower the following spring. It was observed growing as a summer annual on two marsh shores at the south of Bluebill Bay, at Delta. S. congestus also occurs as a pioneer in arctic communities (Lambert, 1976).

Plants up to 150 cm can be produced when conditions are optimal. Plants are tolerant and can flower when flooded as long as the floral apices can emerge from the water. The species is able to survive as single individuals or small populations during stable water levels until drying conditions again allow it to proliferate.

Germination

It has been reported that Chenopodium rubrum germinates best in full sunlight (Cumming, 1963) with high alternating temperatures (Cumming, 1959) and abundant nutrients (Williams, 1969). Seeds must be on or very near the soil surface (<3 mm) for emergence to occur. The seeds are long lived (Williams, 1969) and can withstand at least two cycles of hydration-dehydration and then germinate with 70% success. This enables seeds to survive the temporary adverse conditions that prevail when soils dry at the surface. When conditions are optimal, carpets of seedlings can appear through quasi-simultaneous germination.

Seedlings

Both field and laboratory studies show survival of seedlings decreases with increasing initial density. At low density in the laboratory survival was 88%, but only 43% in the field. At high density, survival was 55% and 5% respectively. Survival in the field was generally less than in the lab due to the waterlogged nature of the soils at RPW.

In natural marshes, recently germinated seedlings may be flooded. In the laboratory there was 27% survival of seedlings flooded with 1 cm water and 3% survival with 5 cm water. No seedlings appeared to survive flooding in the field. Innundated plants are not well anchored in the soil and in natural situations wind action can uproot them.

Habit and Phenology

C. rubrum exhibits phenotypic plasticity in response to environmental conditions (Williams, 1969; Cook, 1976). On the exposed clays of the Delta Borrow Pits, where pH's are close to 8 and conductivity is about 5 mmhos cm^{-2}, a prostrate form appears. Williams and Ungar (1977) found environmental stress affected morphology and development of Suaeda depressa to produce a depressed form. The seedling stage is probably the most critical in determining shape. Ungar (1974) reported seedling growth of Hordeum adversely affected by increasing salinity.

Available nitrogen and other nutrients are increased in soils that are exposed after flooding (Kadlec, 1960). The largest plants are produced when germination occurs early and in nitrogen rich soils (Williams, 1969). Data presented here show that continuously waterlogged soils are adverse to C. rubrum growth.

Availability of nutrients also affects leaf size, fleshiness and degree of branching of the inflorescence (Williams, 1969). Leaves are smallest in waterlogged habitats and when shaded. In impoverished sites, red pigments on leaf margins and the lower surface become more pronounced, leaves are fleshy and only slightly lobed. Cary (1971) found leaf thickness in *C. album* increases as a response to decreased water potential brought about by increased salinity. Apical dominance is reduced and degree of branching is greatest when resources are abundant (Cook, 1976). In waterlogged or crowded situations plants are unbranched. Disturbed sites produce the most robust specimens as there is little competition for available resources.

C. rubrum begins to flower in mid-August. The quantity of seed produced is a complex function of resource availability until flowering is induced because reduced apical dominance allows development of many axillary branches which may differentiate into floral structures (Cook, 1976). Flowering is rapidly induced in late season plants but produces only small quantities of seed (Cumming, 1959).

Management

The drawdown is a commonly used marsh management technique and has been used at Delta to stimulate *C. rubrum* growth. Recently drained mud is required for germination, but time of exposure is important. Early season drawdowns encourage growth of emergents, but drawdowns after mid-summer shorten growing time and result in low seed production. Early July germination appears optimal.

The field seeding experiments show the importance of reducing competition from emergents to maximize *C. rubrum* production. Although adverse water conditions confounded results, it is apparent that residual seed is abundant at Delta and it is probably unnecessary to resort to seeding.

C. rubrum is considered a desirable species because it is attracting to ducks. In the fall, green- and blue-wing teal flock to flooded sites where there is abundant *C. rubrum* and the sportsman is assured a good hunt.

Stable water levels hasten the infilling of marshes while drawdowns are beneficial because drainage of flooded soils improves their nutrient status (Kadlec, 1960). The resultant growth of annual species and germination and expansion of perennial emergents create a number of habitats. The plants provide substrates for the build up of invertebrate and then vertebrate populations important in marsh food webs (Krapu, 1974). Water level fluctuations are vital to the long term survival of marsh ecosystems and where necessary can be produced by artificial means.

Sound management is based upon an understanding of the requirements of the species affected by water level changes. The knowledge of the ecology of *C. rubrum* and *S. congestus*, two important drawdown species, has been advanced by this research, but there are many others to study before the results of any management project can be anticipated.

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APPENDIX I

SPECIES LIST

PLANTS MENTIONED IN THE THESIS

SOURCE - Scoggan, 1957

Acer negundo L.
Agropyron repens (L) Beauv.
Amaranthus retroflexus L.
Aster brachyactis Blake
Atriplex patula L.
Beckmannia syzigachne (Steud.) Fern.
Bidens cernua L.
Carex atherodes Spreng.
Ceratophyllum demersum L.
Chenopodium rubrum L.
Cicuta maculata L.
Cirsium arvense (L.) Scop.
Cornus stolonifera Michx.
Eleocharis palustris (L.) R. and S.
Epilobium glandulosum Lehm. var. adenocaulon (Haussk.) Fern.
Fragaria virginiana Duchesne
Fraxinus pennsylvanica Marsh var. subintegerrima (Vahl.) Fer.
Galium trifidum L.
Hordeum jubatum L.
Humulus lupulus L.
Impatiens capensis Meerb.
Lycopus asper Greene
Melilotus alba Desr.
Mentha arvensis L. var. villosa (Benth.) Stewart
Myriophyllum exalbescens Fern.
Phragmites communis Trin. var. berlandieri (Fourn.) Fern.
Polygonum coccineum Muhl.
Populus deltoides Marsh
Potamogeton pectinatus L.
P. richardsonii (Benn.) Rydb.
Prunus virginiana L.
Puccinellia nuttalliana (schultes) Hitche.
Quercus macrocarpa Michx.
Ranunculus cymbalaria Pursh.
R. sceleratus L.
Rhus radicans L. var. rydbergii (Small) Rehd.
Rorippa islandica (Oeder) Borbas var. fernaldiana Butt. and Abbe
Rosa acicularis Lindl.
Rumex maritimus L. var. fueginus (philippi) Desen.
Salicornia rubra Nels.
Salix amygdaloides Anderss.
S. interior Rowlee
Sambucus pubens Michx.
Scirpus acutus Muhl.
S. fluviatilis (Forr.) Gray
S. paludosus Nels.
S. validus Vahl.
Scolochloa festucacea (Willd.) Link
Senecio congestus (R. Br.) DC.

Sonchus arvensis var. *glabrescens* Guenth., Grab., and Wimm.
Sparganium eurycarpum Engelm.
Spartina pectinata Link.
Stachys palustris L. var. *pilosa* (Nutt.) Fern.
Suaeda depressa (Pursh.) Wats.
Teucrium occidentale Gray
Typha latifolia L.
Ulmus americana L.
Urtica dioica L. var. *procera* Wedd.