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 $50^{O}10''$ 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

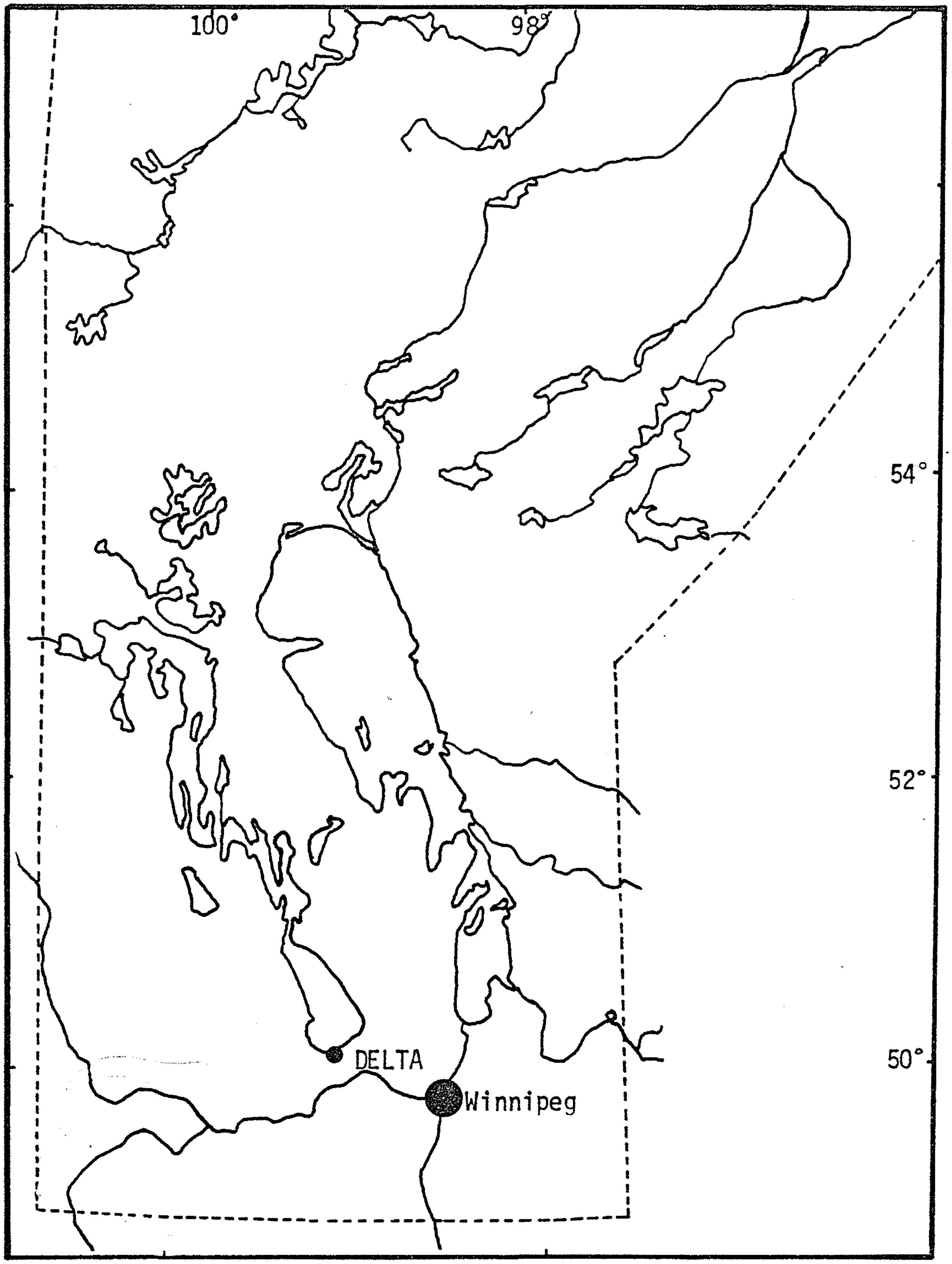


FIGURE 1: Location of the Delta Marsh in southern Manitoba.

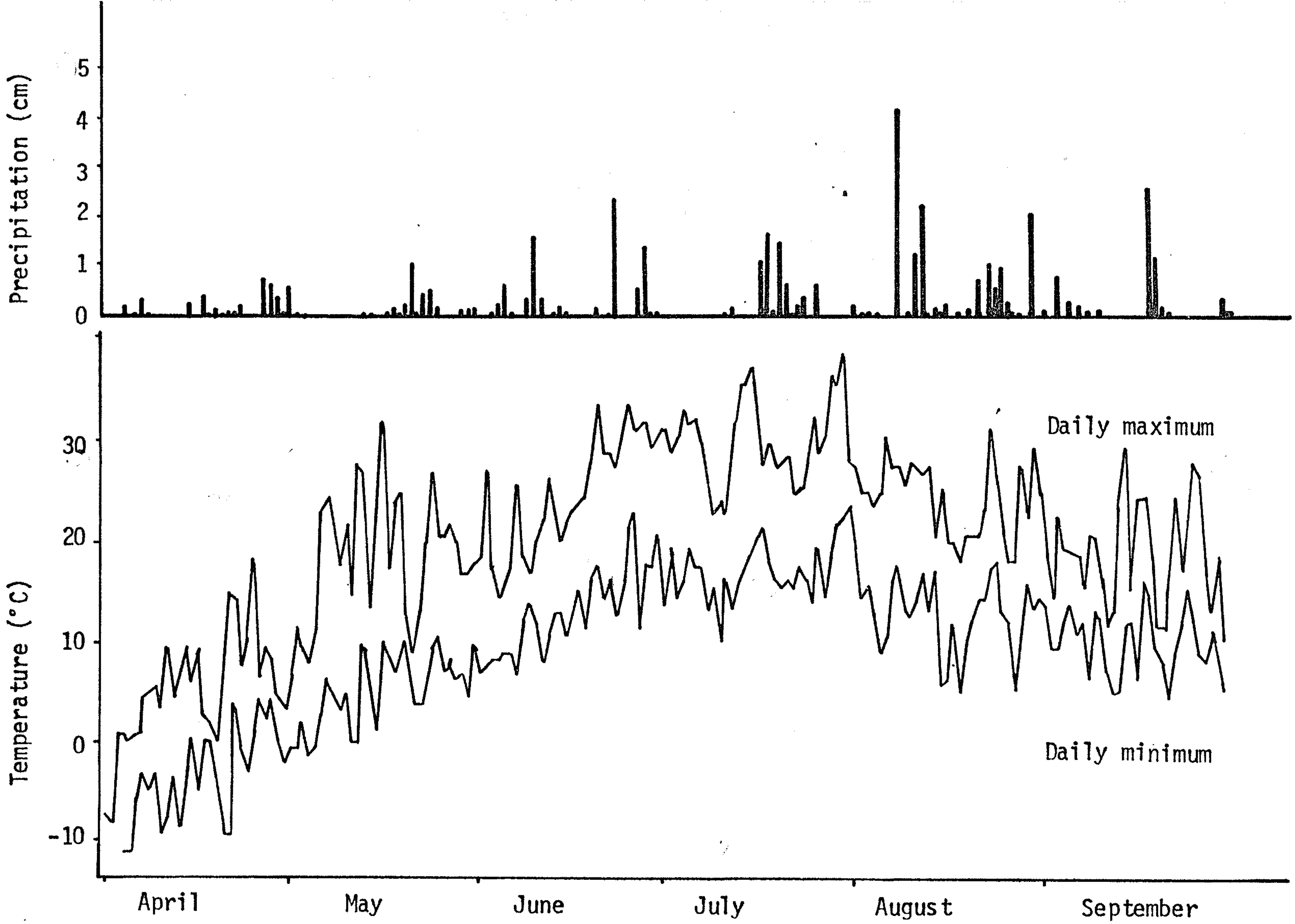
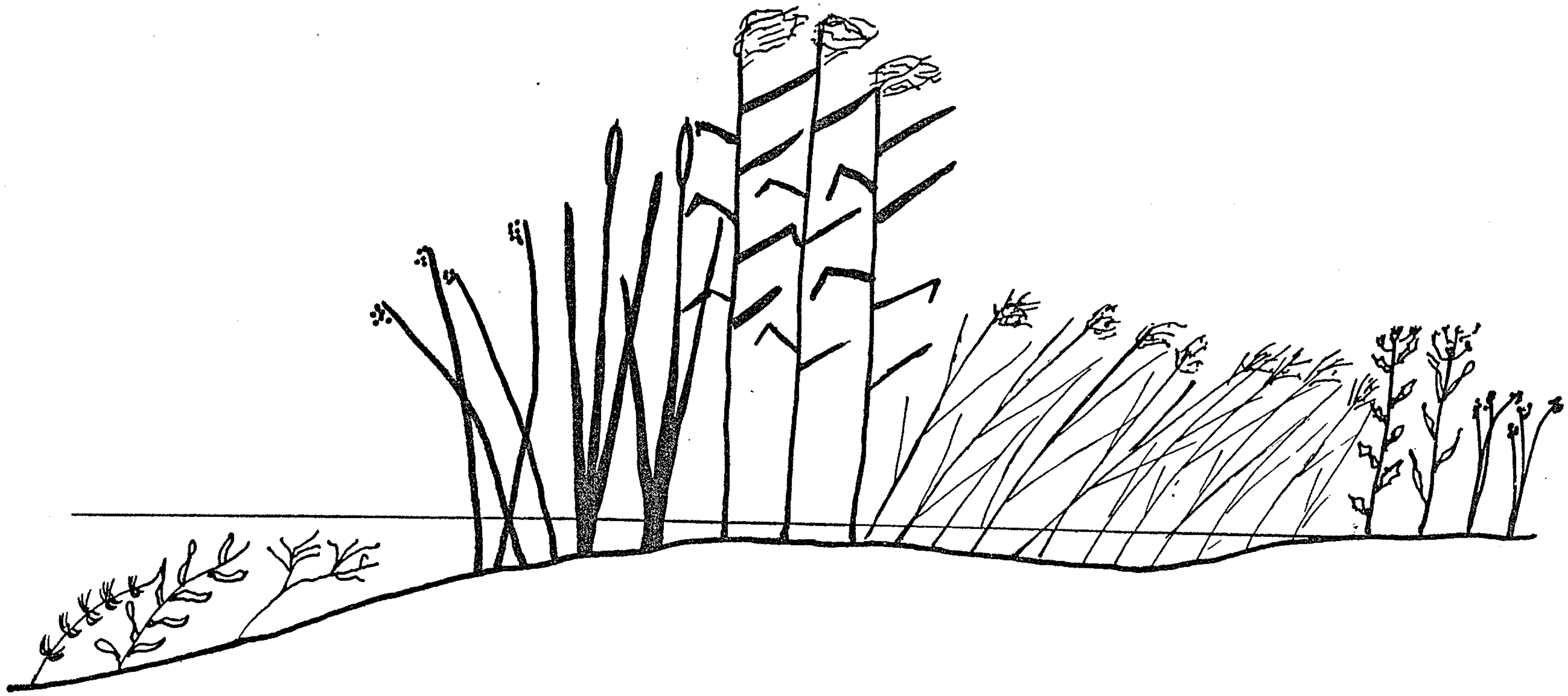


FIGURE 2: Daily maximum and minimum temperatures and rainfall at Delta, summer 1975.

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 Potamogeton richardsonii P. pectinatus	Scirpus acutus Typha latifolia Phragmites communis	Scolochloa festucacea	Cirsium arvense Sonchus arvensis Urtica dioica Stachys palustris Spartina pectinata

FIGURE 3: Zonation of vegetation in the Delta Marsh.