

ENVIRONMENT AND ECOLOGY OF *Scirpus maritimus* L.  
var. *paludosus* (Nels.) Kük. IN SALINE  
WETLANDS OF THE CANADIAN PRAIRIES

A Thesis

Submitted to

The Faculty of Graduate Studies

University of Manitoba

In Partial Fulfillment

of the Requirements for the Degree

Doctor of Philosophy

by

Victor James Lieffers

January 1981

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## ABSTRACT

Seasonal changes in water volume and water and sediment salinity were monitored at three shallow, closed, saline wetlands in Saskatchewan in 1978 and 1979. Porter Lake, the main study site was dry in 1978 and flooded in 1979. When dry, the salinity of surface sediments was higher than sediments 50-60 cm deep, and those in the lake centre were more saline than at the shoreline. Upon reflooding in 1979, there was a large, immediate decrease in surface sediment salinity and surface layers were less saline than sediments 50-60 cm deep. Over the summer in 1979, the water salinity showed a continuous increase and the mass of dissolved salts within the water volume increased fivefold. The ionic proportions of the major salts within the water remained relatively constant. Differences in the ionic proportions of salts within the sediments at various basin positions and depths, appear to be related to the differences in the solubility of the salts and where they are precipitated as the lake water levels recede. Problems in saline lake classification and management are discussed.

The life cycle and seasonal growth of *Scirpus maritimus* L. var. *paludosus* (Nels.) Kük. were monitored, biweekly, at three wetlands in Saskatchewan in 1978 and 1979. Culms sprout from over-wintered tubers in May and lateral rhizomes extend outward and produce tillers and new tubers. Flowering occurs in late June and seed is ripe by August. Shoot senescence begins in early August and by winter all the shoots die.

The below- to above-ground biomass ratio of the *S. maritimus* clones increases in late summer. At one site, high water levels and a resulting drop in salinity, caused a 22-fold difference between the above-ground standing crop in 1978 ( $27 \text{ g/m}^2$ ) and in 1979 ( $600 \text{ g/m}^2$ ). Maximum stem density reached  $380 \text{ stems/m}^2$  by late July, slightly before the maximum standing crop of  $625 \text{ g/m}^2$  was attained. A mathematical equation predicting *S. maritimus* seasonal above-ground standing crop was developed using water depth and conductivity as predictor variables.

*Scirpus maritimus* is found in saline wetlands in the prairie and parkland regions of the Canadian prairies. Within the wetland basins the position and extent of the *S. maritimus* is thought to be dependent upon the mudflat salinity during germination and seedling establishment. The peak standing crop of *S. maritimus* was monitored at 24 saline wetlands in the Canadian prairies.

Multiple regression analysis showed that *S. maritimus* standing crop decreased logarithmically with increasing salinity. In water deeper than 35 cm, individual stems were taller, had a higher rate of flowering and produced larger inflorescences while stem density and proportion of below-ground biomass were reduced compared to shallower depths. The below- to above-ground biomass ratio was highest at shallow water depths and high salinity.

Tubers of *S. maritimus* may remain dormant during dry periods and sprout when the site refloods. In July and August,

at many of the flooded sites, roots on the young tubers were killed, probably by  $H_2S$ .

Two phytophagous Curculionidae (Coleoptera) were found to feed upon *S. maritimus*, *Endalus* sp. utilising seeds and *Sphenophorus aequalis* Gyllenhal tubers. The *Endalus* sp. is parasitized by an *Eupteromalus* sp. (Hymenoptera:Pteromalidae). Insect distribution, population status, life cycle and their impact upon *S. maritimus* were assessed.

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## ACKNOWLEDGEMENTS

I would like to express my gratitude to all who assisted me over the course this study:

Dr. J.M. Shay, thesis supervisor, provided encouragement and constructive criticism throughout the study. Her continuous energy and enthusiasm are an inspiration. Discussions and guidance by my committee members (Drs. A.J. Macaulay, D. Punter and J. Reid) are appreciated.

Statistical advice throughout the study was ably provided by Dr. Bruce Johnston and for the seasonal growth section by Dr. Peter Larkin. I am grateful for the discussions with Drs. J. Barica, C. Booy, T. Kewen and B. Newbury on lake hydrology.

I would like to thank Dr. T.Galloway for information on insect ecology and taxonomy and for the taxonomic determinations; *Endalus* sp. D.E. Bright, *Eupteromalus* sp. C.M. Yoshimoto, *Sphenophorus aequalis* D.R. Whitehead.

I would like to thank my committee members as well as Dr. H. Kennedy, Dr. P.A. Larkin, Dr. G.G.C. Robinson, Dr. C.T. Shay and D.J. Thompson for review of all or parts of this thesis. Discussions and assistance by staff and students of the Dept. of Botany are also appreciated.

Assistance in 1977 was provided by Wildlife Research, Saskatchewan Dept. of Tourism and Renewable Resources. In 1978, 1979 and 1980 research support was supplied by Ducks Unlimited (Canada) and the University of Manitoba Northern Studies Committee. Scholarships from the University of

Manitoba and from the Natural Sciences and Engineering Research Council of Canada are also gratefully acknowledged.

Last but by no means least, I am indebted to Patricia A. Larkin, who through all phases of this study offered encouragement, assistance and useful advice. A large part of this work can be attributed to her efforts.

## INTRODUCTION

Wetlands are an important feature of the landscape in the Canadian prairies, providing wildlife habitat, landscape diversity and groundwater conservation. Because of the drainage of freshwater marshes, saline wetlands are becoming increasingly important in the wetland spectrum of the prairies. If wetland production in the prairies is to be maintained, saline marshes will have to play a proportionately larger role. Effective management of these wetlands must primarily consider *Scirpus maritimus* L. var. *paludosus*<sup>1</sup> (Nels.) Kük., the dominant and frequently the only emergent macrophyte to flourish in saline wetlands. Waterfowl food studies by Keith and Stanislawski (1960), Chura (1961), George (1963) and Serie and Swanson (1976) indicate that the seeds, leaves and stems of *S. maritimus* are important food items for both adult and juvenile ducks.

As little is known about *S. maritimus* in the Canadian prairies, the present study began with a consideration of the ecology of the species. This included an investigation of the seasonal changes in density, clonal development and above-ground standing crop; the peak standing crop of components of the clone, i.e. flowering culms, inflorescences, tillers and below-ground portions and biomass allocation to each component; other factors which affect *S. maritimus* growth and reproduction; and the distribution of the species within the prairies and within the saline lakes themselves. At all times the plant performance was related to water depth and salinity.

<sup>1</sup> Formerly *Scirpus paludosus* Nels.; taxonomic change by Koyama (1962).



Because of the large seasonal and yearly variation in water levels, and consequently in salinities within closed, shallow, saline wetlands, it is essential that management efforts directed at *S. maritimus* be based upon an understanding of how water levels and other factors affect the wetland salinity. Since much of this information was not available, the seasonal change in water level and volume and in sediment and water salinity were also considered.

## LITERATURE REVIEW

Basic limnological data from saline lakes in the Canadian prairies (Rawson and Moore 1944; Driver 1965; Roskowska and Roskowski 1969; Hammer 1978; Hammer and Haynes 1978) indicate that most of the highly saline lakes are shallow, closed basins with  $\text{Na}^+$  or  $\text{Mg}^{++}$  and  $\text{SO}_4^-$  as dominant ions and most are alkaline (water pH 7.5 - 10).

Stewart and Kantrud (1971), Millar (1976) and Cowardin et al (1979) have all developed salinity classification schemes which include prairie saline wetlands. The system of Millar (1976) is the simplest and probably most meaningful for these shallow wetlands, considering their variability from year to year; categories are (in mmhos/cm) fresh ( $< 2$ ), moderately saline (2-15) saline (15-45), and hypersaline ( $> 45$ ). Moss and Moss (1969) described a wetland where decreasing water levels caused a massive salinity increase and necessitated reclassification of the wetland into a much higher salinity category. None of the classification schemes adequately handle this type of seasonal and yearly variability in salinity.

The prairie region is subjected to climatic cycles (Millar 1973; van der Valk and Davis 1978) which cause dramatic shifts in wetland water levels. A more complete discussion of these 5-20 year cycles is given in van der Valk and Davis (1978).

Seasonal and yearly changes in water level and salinity have been recorded for many closed saline basins (Carpelan 1958; Langbein 1961; Bayly and Williams 1966; Moss and Moss 1969; White and Hartland-Rowe 1969; Blinn 1971; Walker 1973;

Kollman and Wali 1976; Hammer 1978). The seasonal change in salinity is greatest in shallow saline lakes (Hammer 1978). During times of water salinity change, the ionic ratio of the major salts within the water of various saline lakes may be both stable (Langbein 1961; Walker 1973; Williams and Buckney 1976) or change with salinity fluctuations (Roskowska and Roskowski 1969; Blinn 1971).

Rawson and Moore (1944), Hammer (1978) and Barica (1977) all suggest that changes in saline lake salinity are related to water volume. Data by Swenson and Colby (1955), Langbein (1961) and Driver and Peden (1977) note that saline lake salinity may relate to both the water volume and changes in the amount of salts within the water volume. This suggests a movement of salts between sediments and water.

Little information has been recorded on the flux of salts between water and sediments. Rollins (1973) was able to show that the flooding of coastal marshes with fresh water causes a migration of salts from the sediments to the water. Hunt (1960) notes that as saline lakes evaporate to dryness, salts are deposited along the receding shoreline in order of their solubilities, with carbonates first, sulfates next and chlorides in the centre of the basin.

Langbein (1961) suggests that in the centre of many shallow saline lakes there are deposits of salts overlain by fine textured sediments. Saline lakes are generally thought to be groundwater discharge sites (Meyboom 1967; Roskowski 1967 and Sloan 1970). The chemistry of this groundwater is

variable and could be highly saline depending upon the path of groundwater flow (Roskowski 1967). At some sites, the direction of groundwater flow could change from spring to fall (Meyboom 1967).

Little work has been done on the productivity of *Scirpus maritimus* in North America. The broad ecological studies of prairie wetlands (Dix and Smiens 1967; Walker and Coupland 1970; Stewart and Kantrud 1971; Millar 1976) note that *S. maritimus* is the dominant emergent in prairie saline lakes. Dodd and Coupland (1966), Stewart and Kantrud (1972) and Ungar (1970 and 1974) in their consideration of the vegetation of saline wetlands in this region, regard *S. maritimus* to occupy the shallow zone around saline wetlands, to be replaced by mudflat annuals in dry conditions and to be out-competed by other emergents in fresh water. Kaushik (1963) notes a decrease in *S. maritimus* stem size with increasing salinity. Ungar (1970) considers that the ionic porportion of the major soluble salts does not influence the distribution of halophyte species, including *S. maritimus*, on the sulfate dominated soils of South Dakota. Millar (1973) notes the disappearance of *S. maritimus* from wetlands subjected to deep water levels.

*Bolboschoenus* Asch. (*Scirpus*) *maritimus* has been more fully studied in Czechoslovakia. Dykyjova (1973) discusses the vertical stand structure and radiation profiles of *S. maritimus* at deep and shallow depths. At water depths 80-90 cm deep *S. maritimus* shoots grow up to 160 cm tall, but stem

density is low, leaves die and young shoots cannot reach the water surface. Standing crop values were 750 to 900 g/m<sup>2</sup> (Dykyjova et al 1971) and 480 g/m<sup>2</sup> (Ondok and Dykyjova 1973) in natural stands.

Dykyjova et al (1972) noted that the root/shoot ratio of *S. maritimus* reached a maximum of 1.2 near the end of the growing season. The tubers of *S. maritimus* are considered to be adapted to anabiosis in dried wetland basins (Hejny 1960 in Dykyjova et al. 1971).

Kaushik (1963) in Utah, reported successful germination from *S. maritimus* seed incubated in distilled water and constant light. With increasing salinity, germination was reduced, as is expected according to Waisel (1972). Seed germination of *S. robustus* Pursh (George 1963) and *S. maritimus* (O'Neill 1972) is thought to be enhanced by soaking the seeds with sodium hypochlorite prior to seeding. This technique was not useful in improving germination of seeds from all geographic sources (George 1977); the inland seed source from Minnesota, gave the poorest germination results. For a Maryland population of *S. robustus* (Dietert and Shontz 1978) germination was enhanced by high temperatures, low salinities, light, scarification and a one month after-ripening period. Ungar (1978) in his review paper, discusses halophyte seed germination more fully while some of the mechanisms of seed dormancy are given by Taylorson and Hendricks (1977).

CHAPTER 1

THE SEASONAL SALINITY REGIME OF THREE SHALLOW  
SALINE LAKES IN SASKATCHEWAN

## INTRODUCTION

It has been well documented that closed, shallow, saline lakes undergo large seasonal changes in salt concentration (Bayly and Williams 1966; White and Hartland-Rowe 1969; Kollman and Wali 1976; Hammer 1978). Generally, during the summer, salinity increases as the water volume decreases due to evaporation. Under winter ice, the salinity of a moderately saline lake was directly related to changes in water volume (Barica 1977). Langbein (1961), using longterm data from several large saline lakes, noted that water salinity in some saline lakes reflects changes in both the water volume and the amount of salt dissolved in it. In coastal marshes flooded with relatively fresh water, salts migrate from the sediments to the water volume (Rollins 1973). Hunt (1960) predicts that as the levels of saline wetlands recede, salts are deposited on the shore in order of their solubilities; carbonates around the margin, then sulfates, and chlorides in the centre. Little work on shallow saline lakes has simultaneously considered the seasonal interchange of salts between the water volume and the sediments and the ion balance of the water and sediments.

The objectives of this study were to monitor the physical and chemical changes in shallow saline lakes, particularly:

- 1) the salinity of the water in relation to its volume;
- 2) the movement of salts between the water and sediments;
- 3) the seasonal changes in the ionic ratios of the water;
- 4) the salt concentrations and ionic proportions in the sediments at various positions and depths within the basin.

## Study Area

Three shallow saline lakes in Saskatchewan were examined in 1978 and 1979. Most of the study effort centred on Porter Lake ( $52^{\circ}11'N;106^{\circ}17'W$ ) while Strap Lake ( $51^{\circ}47'N;105^{\circ}44'W$ ) and Blondie Lake ( $52^{\circ}02'N;106^{\circ}18'W$ ) were also considered. All the lakes are less than 1.0 m deep, subjected to mixing by wave action and have  $Na^{+}$  or  $Mg^{++}$  and  $SO_4^{-}$  as the dominant ions. Both Porter and Blondie Lakes are closed basins with no surface outflow. Strap Lake, a Ducks Unlimited project, had its water levels artificially raised by 45 cm, in August 1979, from water supplied via a canal running immediately adjacent to the wetland. Limnological features of saline wetlands within this region are discussed by Rawson and Moore (1944); Hammer (1978); Hammer and Haynes (1978). Fortunately conditions were relatively dry in 1978 and wet in 1979, providing variability in water regimes in a short time period.

## METHODS

### Field Study

Porter and Blondie Lakes were sounded in May 1979, 10 cm interval contour maps were drawn and area-volume curves charted. For Strap Lake, this information was made available by Ducks Unlimited (Canada).

In 1978, Porter Lake was dry except for a short period in April and early May. Sediment sampling stations were established on the shoreline, mid-slope and centre of the basin. Biweekly, sediment cores down to 60 cm were extracted with a Livingstone corer. The 0-10 cm, 20-30 cm and 50-60 cm levels were retained and air-dried.



In 1979, three similar sampling stations were established at Strap and Blondie Lakes. Samples were taken, in triplicate, at all three lakes at monthly intervals. For the first three sampling periods, portions of the sediment samples at each position and depth were sealed in polyethylene bags and stored for moisture and porosity analysis. The remaining portions of the sediment samples were air-dried. Water depths were measured on a water depth gauge established near the centre of the lake.

Water samples were collected in 1.0 L polyethylene bottles from 15 cm below the water surface in the open water zone of the lake. Phenolphthalein alkalinity and total alkalinity (APHA 1971) and pH (Fisher model 150 pH meter) were measured at the time of collection. Two portions of the sample were filtered, one acidified with 1.0 ml of 4 N  $\text{H}_2\text{SO}_4$  per 100 ml sample and the second frozen. Specific conductance was measured on an unfiltered portion of the sample using a Radiometer CDM2e conductivity meter standardized at 25 °C.

#### Laboratory

Air-dried sediments were ground with a mortar and pestle and pH, alkalinity and specific conductance of saturated paste extracts (McKeague 1976) were determined. One of the triplicate sediment samples was analysed for individual ions.

Chloride concentrations for both the sediment extracts and the frozen water samples were determined by titration with mercuric nitrate and a diphenylcarbazone indicator (Stainton et al. 1977). Sulfate determinations were made by the barium chloride turbidimetric technique (APHA 1971). A Perkin-Elmer 403 atomic absorption spectrophotometer and the techniques

outlined in its manual (1973) were used in the determination of  $\text{Na}^+$ ,  $\text{Mg}^{++}$ ,  $\text{Ca}^{++}$  and  $\text{K}^+$  concentrations. Sediment moisture content and porosity were determined by drying to a standard weight at  $105^\circ\text{C}$ , a weighed, standard volume of the polyethylene-bagged sediments. Sediment texture was estimated according to Killmer and Alexander (1949); organic matter by ashing a known weight for 24 hours at  $425^\circ\text{C}$ . This temperature does not cause significant loss of carbonates (Davies 1974). Total dissolved solids in the water (TDS) were determined on filtered water samples by evaporating to standard weight at  $105^\circ\text{C}$  (Rawson 1951).

#### Data Analysis

Student's t-test was used to compare sediment conductivities for the different years, positions and depths. Ionic ratios were calculated using concentrations in meq/l. Analysis of variance comparing sediment  $\text{Na}^+/\text{Mg}^{++}$  and  $\text{SO}_4^{=}/\text{Cl}^-$  ratios was carried out using the data from the first five sampling periods in 1979 and five dates in 1978 most closely matching the 1979 dates. This provided a balanced analysis of variance design. The total mass of dissolved solids within the water was calculated from water TDS X water volume.

## RESULTS

As the data from Porter Lake were most complete and trends at Blondie and Strap Lakes were similar to Porter, except where noted, this paper focuses upon the results obtained at Porter Lake in 1978 and 1979.

The sediments at Porter Lake (Table 1-1) are predominantly silts with 2-7 % organic matter and when inundated, showed a decrease in moisture content and porosity with increasing depth.

Porter Lake was flooded for only a short period in April and early May in 1978. Throughout the summer the sediments remained wet under a thin dry surface crust. At all three sediment sampling positions, the 0-10 cm layers had significantly higher conductivities ( $P < .02$ ) than the sediments at the 20-30 cm level which in turn were higher ( $P < .02$ ) than the 50-60 cm level (Fig. 1-1). The sediments at the centre position had significantly higher conductivities than sediments at the same depth at the mid-slope which were more saline than those from the shoreline position ( $P < .01$ ). There were no obvious seasonal trends in the conductivities at any particular position or depth (Fig. 1-1).

In 1979, Porter Lake was flooded to 60 cm deep and the sediments at the three sampling stations were covered by water. The centre position still had significantly higher conductivities ( $P < .01$ ) than the sediments at the same depth at the mid-slope, which had higher conductivities than the shoreline (Fig. 1-2). The mean conductivity of sediments at the 0-10 cm depth at all three positions decreased from 1978 to 1979,

Table 1-1 Physical properties of Porter Lake sediment core samples, 1979.

| Core       |            | Percent   |           |                |      |      |      |
|------------|------------|-----------|-----------|----------------|------|------|------|
| Position   | Depth (cm) | Moisture* | Porosity* | Organic Matter | Sand | Silt | Clay |
| Shore-line | 0-10       | 47.5      | 66.6      | 4.6            | 4.8  | 77.2 | 17.9 |
|            | 20-30      | 27.2      | 48.8      | 3.1            | 21.1 | 66.7 | 12.2 |
|            | 50-60      | 25.1      | 47.7      | 2.3            | 5.6  | 78.5 | 16.0 |
| Mid-Slope  | 0-10       | 46.0      | 69.7      | 4.6            | 1.1  | 95.8 | 3.1  |
|            | 20-30      | 29.3      | 52.0      | 3.3            | 4.6  | 95.2 | 0.2  |
|            | 50-60      | 26.3      | 47.6      | 3.8            | 7.5  | 92.3 | 0.2  |
| Centre     | 0-10       | 41.2      | 63.9      | 5.4            | 0.8  | 96.5 | 2.8  |
|            | 20-30      | 30.6      | 52.0      | 5.7            | 5.7  | 91.9 | 2.4  |
|            | 50-60      | 29.2      | 52.7      | 7.1            | 6.3  | 82.3 | 11.4 |

\* Mean of May 8, June 1 and June 28 samples (all positions inundated for the three periods)

Fig. 1-1 Seasonal specific conductance of Porter Lake sediments at various basin positions and depths, 1978.

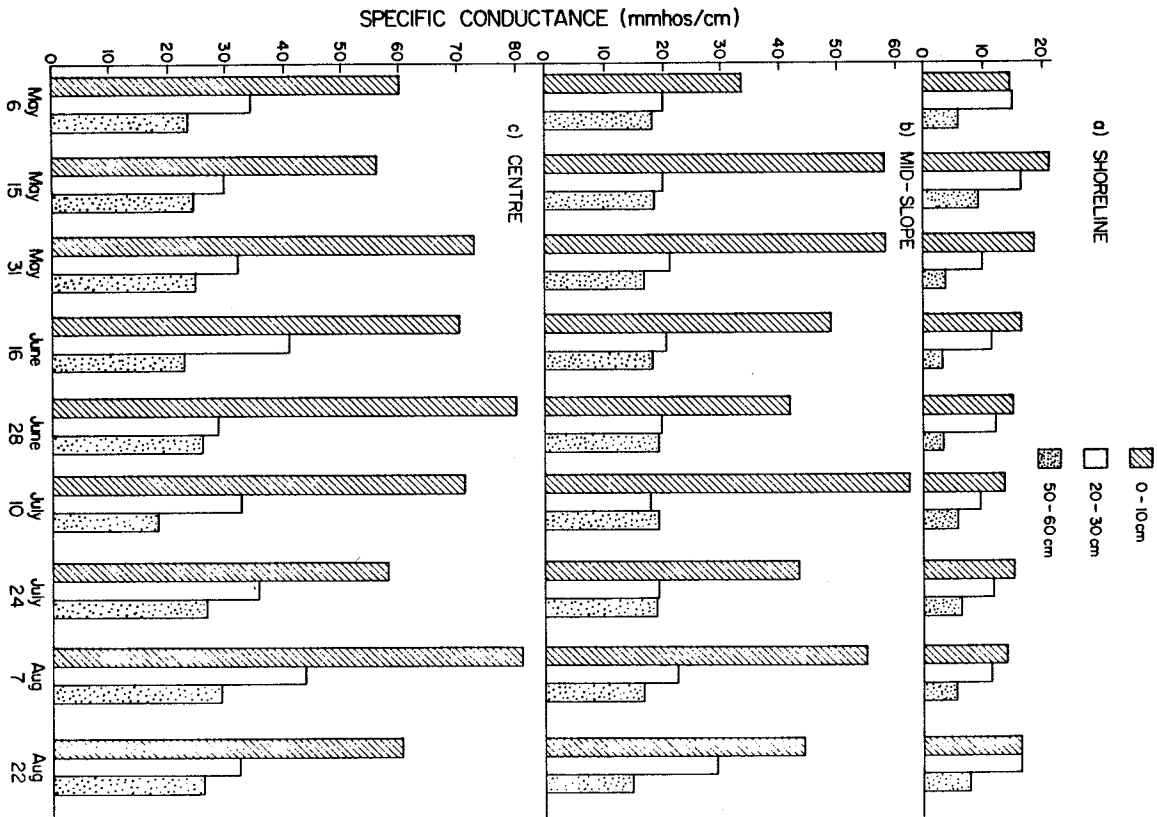
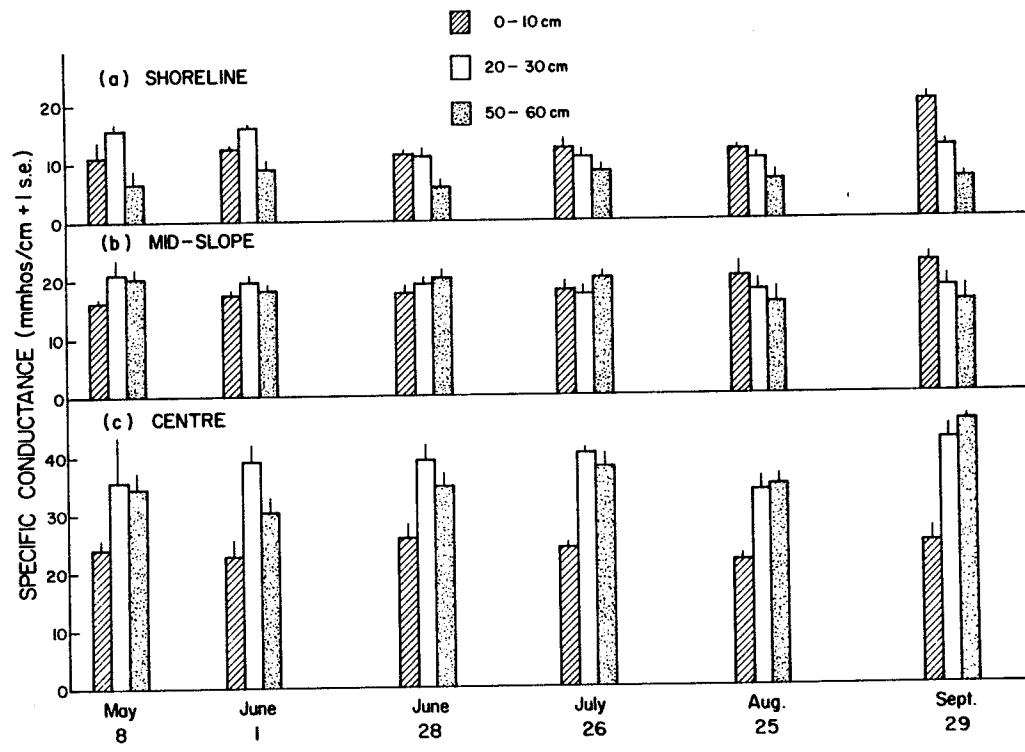


Fig. 1-2 Seasonal specific conductance of Porter Lake sediments at various basin positions and depths, 1979. ( $\pm 1$  standard error).

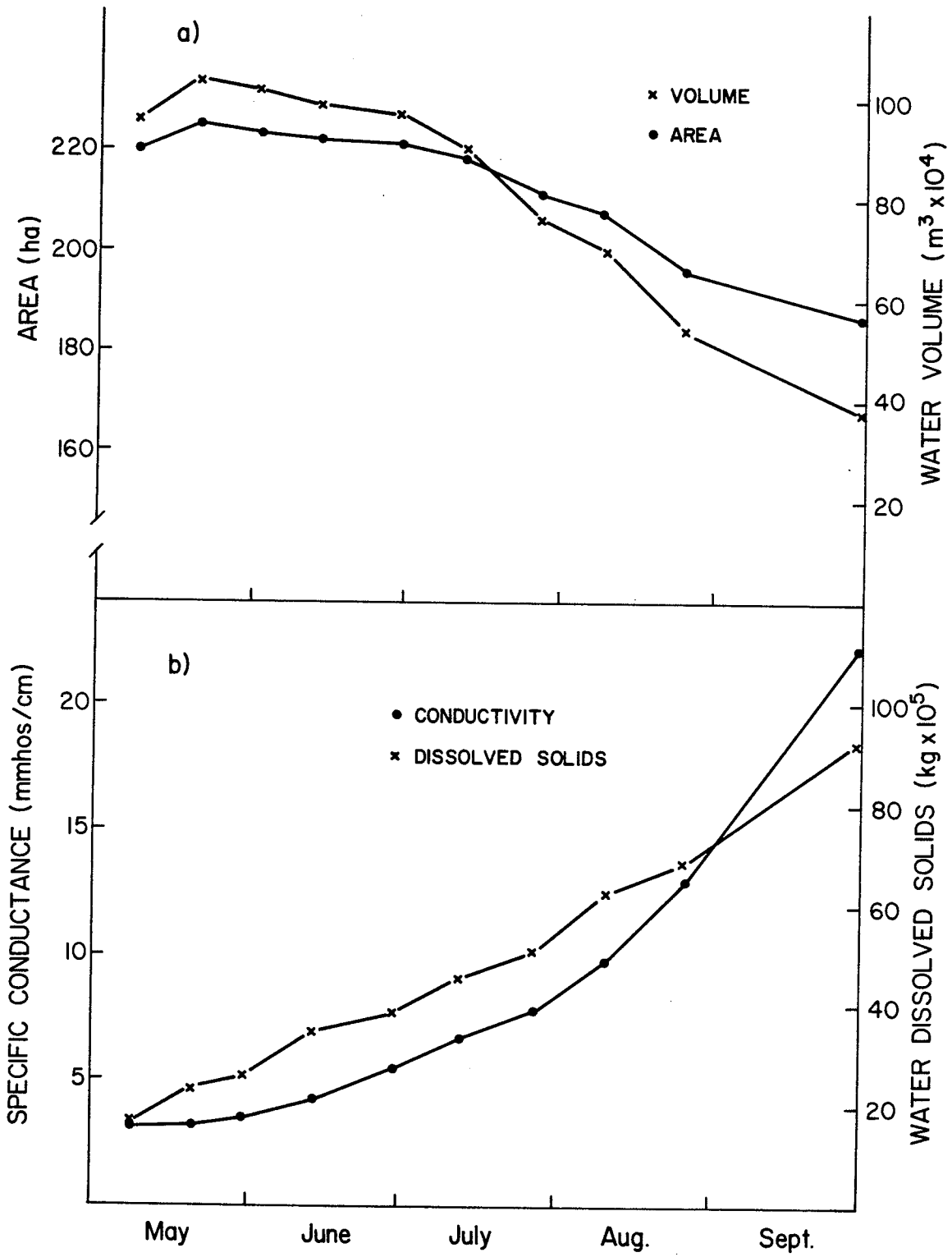




particularly at the centre position which dropped from 68 to 23 mmhos/cm ( $P < .001$ ). The sediments at the 50-60 cm depth of the centre position had significantly higher conductivities ( $P < .01$ ) in 1979 than in 1978. After August, water levels had dropped sufficiently that the shoreline sampling position was dry. Surface sediment conductivities were higher ( $P < .05$ ) than at any other time during the season. This was also noted at Blondie and Strap Lakes (Appendix IV) where, as the water levels receded, the mud flat zones created, had higher surface conductivities than surface sediments in the flooded area.

In 1979, the maximum water volume of Porter Lake was reached by May 20 and by late September the volume had decreased 63 % (Fig. 1-3). Due to the almost uniformly flat bottom of the basin there was only an accompanying 17 % decrease in the flooded area. During the summer, water conductivity increased from 3.08 to 22.2 mmhos/cm and the mass of dissolved solids within the water volume had increased almost fivefold by September. A noteworthy feature corresponding with this, was the lack of any seasonal decrease in sediment conductivity as the mass of water salts increased. The 0-10 cm level of the centre position had conductivities near 23 mmhos/cm throughout the season. Water conductivities were much lower than 23 mmhos/cm for most of the season and a large concentration gradient existed between sediments and water.

Fig. 1-3 Porter Lake, 1979. a) Water volume and flooded area. b) Water specific conductance and mass of dissolved solids.



Blondie Lake was dry by August 1978 and was reflooded in the spring of 1979. By September this 9 ha lake had an 83 % reduction in water volume (Fig. 1-4). Water conductivities increased throughout the season. The weight of dissolved solids within the water volume increased fivefold from early May to the end of July, after which time there was a decrease in the mass of dissolved solids within the water. As with Porter Lake, surface sediment conductivities initially showed a striking decrease upon reflooding, but remained higher than the water conductivities.

Strap Lake was nearly dry by late fall 1978 and was reflooded in 1979. This lake had a 99 % decrease in volume by mid-August and may have been completely dry for several days prior to being refilled, in late August (Fig. 1-5) by Ducks Unlimited. The water conductivity increased to a maximum when the water volume was most reduced. Conductivity decreased again when the lake was refilled. The mass of dissolved solids in the water peaked in mid-June after a 17 % reduction in water volume and decreased more than 12-fold when the lake volume was smallest. Upon refilling, the mass of dissolved solids increased again to the spring levels.

The F values and probabilities for the analysis of variance comparing sediment  $\text{Na}^+/\text{Mg}^{++}$  and the  $\text{SO}_4^{=}/\text{Cl}^-$  ratios at Porter Lake for the different basin positions and depths, the sampling month and the year are presented in Table 1-2. The  $\text{Na}^+/\text{Mg}^{++}$  ratio had a significant depth X year interaction, with 1979 having a lower mean ratio in the surface layers

Fig. 1-4 Blondie Lake, 1979. a) Water volume and flooded area. b) Water specific conductance and mass of dissolved solids.

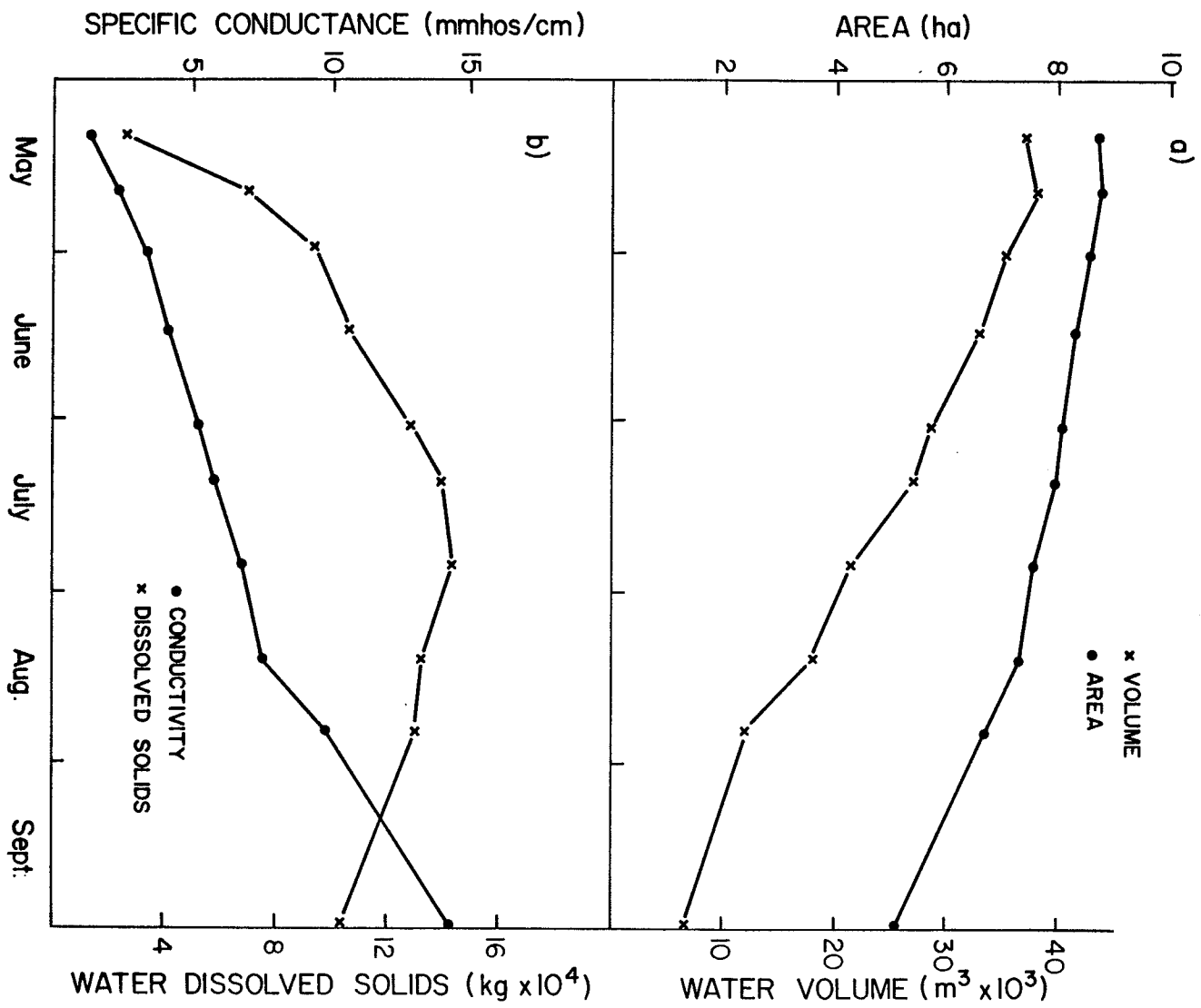


Fig. 1-5. Strap Lake, 1979. a) Water volume and flooded area. b) Water specific conductance and mass of dissolved solids.

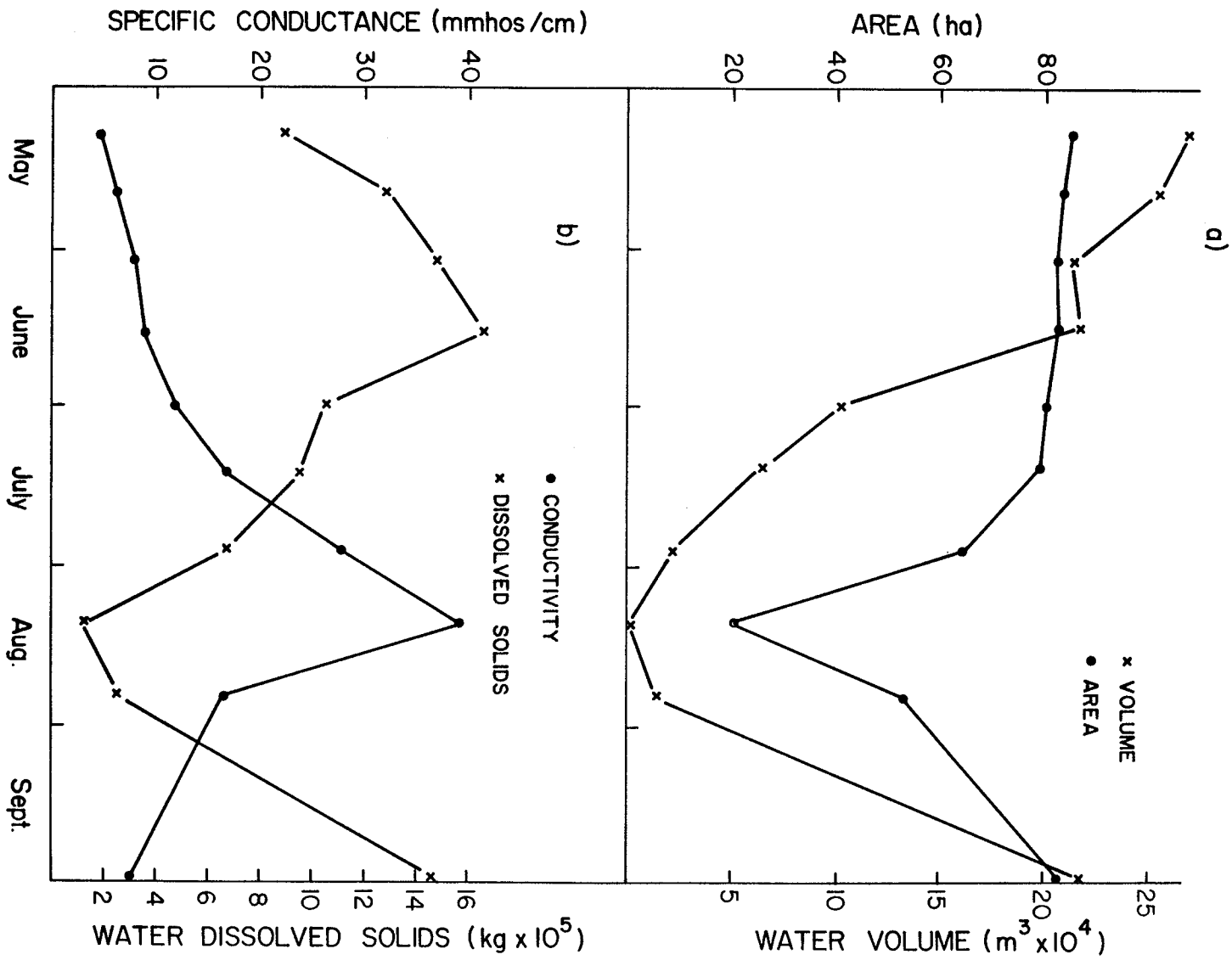




Table 1-2 Analysis of variance of the  $\text{SO}_4^{=}/\text{Cl}^-$  and the  $\text{Na}^+/\text{Mg}^{++}$  ratios of Porter Lake sediments in relation to the year (Y), month (M), and core position (P) and depth (D). Error d.f. = 51.

|          | d.f. | $\text{SO}_4^{=}/\text{Cl}^-$ |        | $\text{Na}^+/\text{Mg}^{++}$ |        |
|----------|------|-------------------------------|--------|------------------------------|--------|
|          |      | F value                       | Pr > F | F value                      | Pr > F |
| Year     | 1    | 47.6                          | .0001  | 0.6                          | .462   |
| Month    | 4    | 0.6                           | .682   | 4.1                          | .006   |
| Position | 2    | 58.3                          | .0001  | 110.3                        | .0001  |
| Depth    | 2    | 7.5                           | .001   | 8.3                          | .0008  |
| Y X M    | 4    | 2.5                           | .053   | 2.1                          | .096   |
| Y X P    | 2    | 2.9                           | .063   | 11.0                         | .0001  |
| Y X D    | 2    | 10.5                          | .0002  | 4.2                          | .021   |
| M X P    | 8    | 0.7                           | .711   | 0.6                          | .754   |
| P X D    | 4    | 3.7                           | .010   | 7.3                          | .0001  |
| M X D    | 8    | 1.6                           | .150   | 0.9                          | .542   |

(Fig. 1-6a). The  $\text{Na}^+/\text{Mg}^{++}$  ratio for basin position (main effect) was highly significant, with the shoreline having the highest ratio (Fig. 1-6b). The significant  $\text{Na}^+/\text{Mg}^{++}$  ratio position X depth interaction, appears to be due to the large decrease in the  $\text{Na}^+/\text{Mg}^{++}$  ratio at the 20-30 cm level of the centre position. The significant  $\text{Na}^+/\text{Mg}^{++}$  ratio for month (main effect) relates to higher ratios in the first two sampling periods.

The sediment  $\text{SO}_4^{=}/\text{Cl}^-$  ratio was significantly lower in 1979 than in 1978 (Fig. 1-6c). There was also a significant year X depth interaction caused by the 1978 0-10 cm depths having proportionately more  $\text{Cl}^-$  than in 1979. The sediment  $\text{SO}_4^{=}/\text{Cl}^-$  ratio for basin position (main effect) (Fig. 1-6d) was highly significant. The shoreline had a much higher ratio than the mid-slope or the centre positions. The significant position X depth interaction relates to the higher  $\text{SO}_4^{=}/\text{Cl}^-$  ratio at the 50-60 cm depth of the centre position.

At Porter Lake, even with the 10-fold increase in salinity over the season, the ionic balance of the major soluble salts remained remarkably stable (Table 1-3). Only the  $\text{SO}_4^{=}/\text{Cl}^-$  ratio decreased significantly during the summer ( $r = -.69$ ,  $p < .05$ ). These ionic ratios in Blondie and Strap Lakes also remained relatively stable (Appendix IV). Increasing salinity however, caused a decrease in the proportion of both  $\text{Ca}^{++}$  and the carbonates.

#### DISCUSSION

It is apparent that the changes in water salinity of the shallow saline wetlands examined are due to changes in water volume and the mass of dissolved salts within the water volume. At the three lakes examined there was an increase

Fig. 1-6 Mean sediment ionic ratios at Porter Lake 1978 and 1979.

- a)  $\text{Na}^+/\text{Mg}^{++}$  ratio for year and core depth.
- b)  $\text{Na}^+/\text{Mg}^{++}$  ratio for basin position and core depth.
- c)  $\text{SO}_4^{=}/\text{Cl}^-$  ratio for year and core depth.
- d)  $\text{SO}_4^{=}/\text{Cl}^-$  ratio for basin position and core depth.

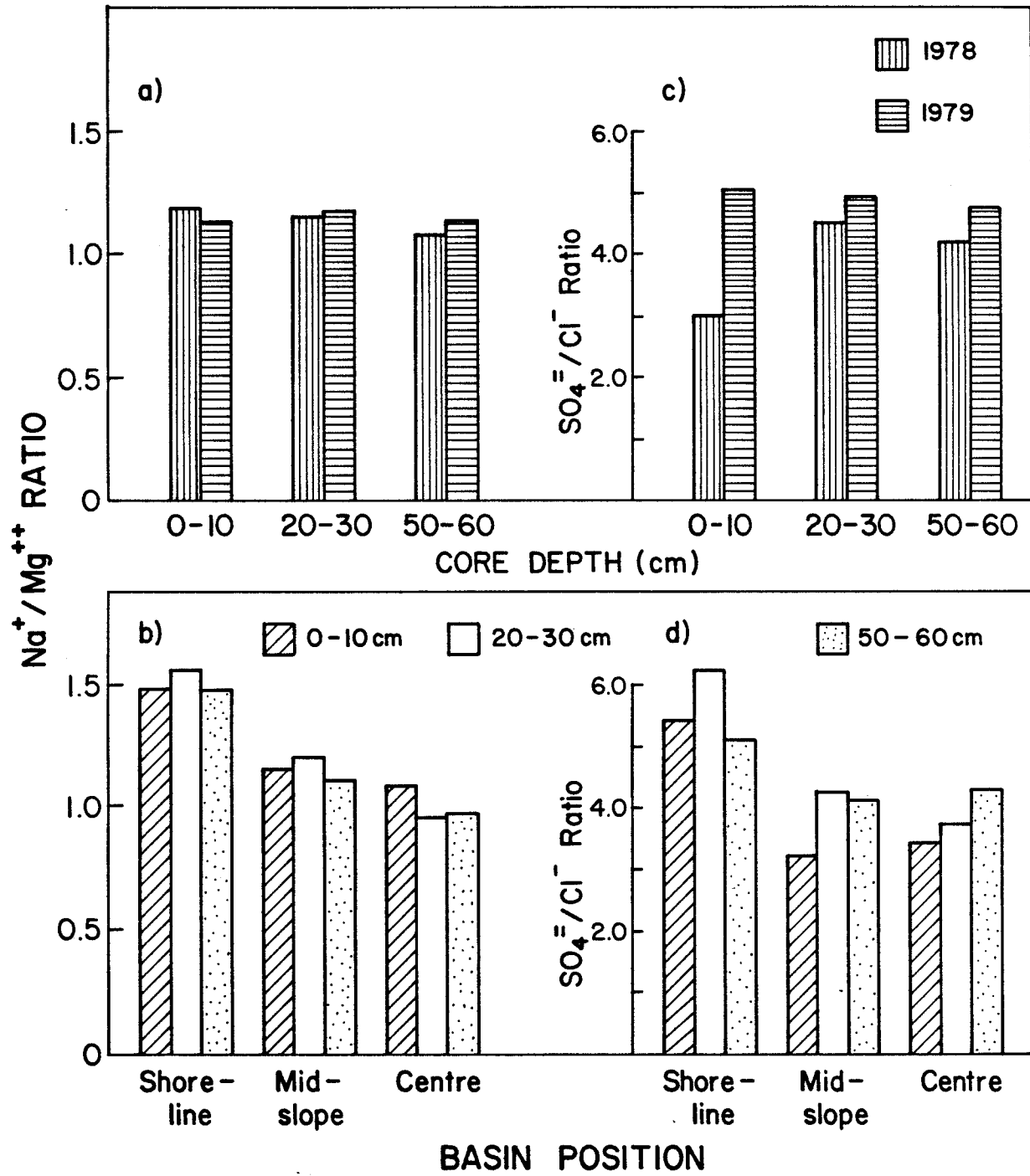


Table 1-3 Chemical composition of Porter Lake water for sampling periods in 1979.

| Sample Date | water    |          | Conductance<br>mmhos/cm | mg/L                         |                 |                              |                               |                 |                  |                  |                | meq/L                             |   |
|-------------|----------|----------|-------------------------|------------------------------|-----------------|------------------------------|-------------------------------|-----------------|------------------|------------------|----------------|-----------------------------------|---|
|             | Field pH | Temp. °C |                         | SO <sub>4</sub> <sup>=</sup> | Cl <sup>-</sup> | CO <sub>3</sub> <sup>=</sup> | HCO <sub>3</sub> <sup>-</sup> | Na <sup>+</sup> | Mg <sup>++</sup> | Ca <sup>++</sup> | K <sup>+</sup> | Na <sup>+</sup> /Mg <sup>++</sup> | SO <sub>4</sub> <sup>=</sup> /Cl <sup>-</sup> |
| May 8       | 8.2      | 3        | 3.08                    | 792                          | 156             | -                            | 143                           | 225             | 90               | 150              | 20             | 1.31                              | 3.7   |
| May 20      | 8.1      | 8        | 3.12                    | 945                          | 167             | -                            | 170                           | 280             | 105              | 160              | 20             | 1.39                              | 4.2   |
| June 1      | 7.8      | 9        | 3.53                    | 1265                         | 198             | -                            | 235                           | 350             | 135              | 225              | 30             | 1.36                              | 4.7   |
| June 14     | 8.2      | 15       | 4.25                    | 1480                         | 344             | -                            | 262                           | 440             | 170              | 245              | 40             | 1.36                              | 3.2   |
| June 28     | 8.2      | 26       | 5.50                    | 1780                         | 417             | -                            | 275                           | 560             | 215              | 270              | 40             | 1.37                              | 3.2   |
| July 11     | 8.9      | 26       | 6.75                    | 2150                         | 563             | 12                           | 250                           | 675             | 260              | 240              | 60             | 1.37                              | 2.8   |
| July 26     | 9.5      | 23       | 7.80                    | 2940                         | 709             | 49                           | 110                           | 945             | 360              | 240              | 70             | 1.38                              | 3.1   |
| Aug. 10     | 8.1      | 19       | 9.80                    | 4000                         | 1000            | -                            | 207                           | 1365            | 480              | 315              | 80             | 1.49                              | 3.0   |
| Aug. 25     | 9.1      | 15       | 13.00                   | 5320                         | 1397            | 6                            | 207                           | 1720            | 690              | 385              | 110            | 1.31                              | 2.8   |
| Sept. 29    | 8.6      | 7        | 22.20                   | 10700                        | 2669            | 6                            | 445                           | 3800            | 1430             | 425              | 190            | 1.40                              | 3.0   |

in the mass of dissolved solids when the water volumes were relatively large. This phenomenon was also observed by Langbein (1961) and Driver and Peden (1977). As lake levels fell and the volume and flooded area were reduced below a critical level, there was a decrease in the mass of dissolved solids in the water, as was observed at Blondie and Strap Lakes (Figs. 1-4 and 1-5). The addition of fresh water to Strap Lake in the fall (water supplied via a canal system) and the return of levels of dissolved solids to the same approximate point as with the equivalent water volume in the spring, indicates that, after a sufficient time delay, the water salinity at a particular volume is probably fairly uniform from period to period. This was also suggested by Langbein (1961).

Upon reflooding with fresh water at Porter Lake, the initial large drop in sediment salinity at the 0-10 cm depths is expected. Highly soluble salts on the sediment surface are rapidly dissolved in the fresh water. The fact that at Porter Lake there was not a continual seasonal decrease in the sediment salinity at the 0-10 cm depths; even though there was a constant increase in the mass of dissolved solids within the water volume is not easily explained. Runoff water from adjacent areas could not contain a sufficient mass of salts to account for the increase in the total mass of dissolved solids in the water. Langbein (1961) however, noted that in the centre of shallow saline lakes there may be deposits of salts overlain by fine textured sediments. Meyboom (1967) discusses how groundwater

is discharged into saline wetlands. This groundwater could itself be highly saline (Roskowski 1967) or it could dissolve part of the salt deposit below the wetland and add this salt to the water volume. The significantly higher salinities in the centre sediments at the 50-60 cm depths in 1979 suggests an addition of salts from below.

Sediments at the 0-10 cm level of the centre position remained at approximately 23 mmhos/cm despite lower water salinities over most of the summer. Jones et al. (1969) and Lerman and Jones (1973), at Lake Abert, Oregon, found significantly higher concentrations of soluble salts in interstitial water of sediments than in the overlying lake water. Lerman and Jones (1973) determined that diffusion, though very slow, is the dominant means of transport of salts from the sediments to the water. The lack of any seasonal decrease in sediment salinity (Fig. 1-2) when Porter Lake was reflooded in 1979 suggests that slow diffusion alone is acting to slowly move salts from the sediments to the water on the areas of the basin floor examined. The large seasonal increase in the mass of dissolved solids in the water (Fig. 1-3) must dominately relate to inputs of salts from localized seepage areas or springs, with ionic diffusion as a secondary contributor of salts. Porter Lake has spring discharge areas on its southern end.

As Strap and Blondie Lakes dried, salts were deposited on the surface sediments, particularly the shoreline. Considering the sediment (0-10 cm) porosity, the increase in salinity and the area, the loss of salts to surface sediments accounted for most of the decrease in the total salts dissolved in the water. In contrast, at Porter Lake in the summer of 1979, the increase in water salinity was partly related to the addition of salts from sources other than the surface sediments. When this wetland dries out completely a portion of the salts will be deposited on surface sediments but some will probably be lost to the groundwater or deep sediments, perhaps by a reversal of groundwater flow (Meyboom 1967). If part of the salt load were not returned there, Porter Lake would show a massive increase in total salinity after the 1979 flooding.

The Position effect was most significant in the analysis of variance of the ionic ratios of Porter Lake sediments. The  $\text{SO}_4^{=}/\text{Cl}^-$  ratio was highest at the shoreline sampling position (Fig. 1-6d) as the  $\text{SO}_4^{=}$  salts are deposited earlier during the drying period, supporting Hunt (1960), that salts are deposited on the receding shoreline in order of their solubilities. Also when Porter Lake dried out in 1978,  $\text{Cl}^-$  salts, being the most soluble, were the last to be deposited on the surface sediment layers and the first to redissolve upon reflooding in 1979. This could explain the significant increase in the  $\text{SO}_4^{=}/\text{Cl}^-$  ratio in 1979 (Fig. 1-6c). The same applies to the  $\text{Na}^+/\text{Mg}^{++}$  ratio. Both  $\text{MgSO}_4$  and  $\text{MgCl}_2$  are more soluble than  $\text{Na}_2\text{SO}_4$  or  $\text{NaCl}$  (Chemistry and Physics Handbook 1979). It is thus reasonable to expect the  $\text{Na}^+/\text{Mg}^{++}$  ratio to be



higher along the shoreline as the  $\text{Na}^+$  salts would be deposited first (Fig. 1-6b).

The relative stability of the ionic ratios of the major salts within the water is initially puzzling in light of the changes in sediment ionic proportions due to differences in solubilities. If the main source of water salts were from a small mass of salts on the wetland surface, over the season, one would expect differences in the ionic proportions of the water as the salts would dissolve at different rates. Seasonal differences in water ionic proportions were observed by Roskowska and Roskowski (1969) and Blinn (1971) in some saline wetlands. If most of the salts within the water were derived from a large pool of salts deep within the sediments or from saline groundwater discharge, the ionic proportions of the water salts could remain relatively constant despite increasing salinity. Langbein (1961) and Williams and Buckney (1976) have also documented cases of stability of water ionic proportions in times of total salinity change.

## CHAPTER 2

THE EFFECTS OF WATER LEVEL ON THE GROWTH AND REPRODUCTION  
OF *Scirpus maritimus* L. var. *paludosus* (Nels.) Kük.

## INTRODUCTION

It is well known that water levels influence the composition of wetland plant communities (Kadlec 1962; Walker 1966; Millar 1973). The effects of water levels on the growth of individual wetland species have been recorded for *Zizania aquatica* L. (Thomas and Stewart 1969), *Scolochloa festucacea* (Willd.) Link. (Smith 1973), *Scirpus acutus* Muhl. and *Scirpus validus* Vahl (Dabbs 1971; Macaulay 1974), and *Juncus gerardii* Lois. (Rozema and Blom 1977). The broad ecological studies of prairie wetlands (Walker and Coupland 1970; Millar 1973) and prairie saline areas (Dodd and Coupland 1966; Ungar 1970, 1974) consider *Scirpus maritimus* L. var. *paludosus* (Nels.) Kük. to occupy the shallow, sometimes dry zone around saline wetlands and to show a wide tolerance to water depth and salinity. Few quantitative data however, have been reported on the effects of water depth on the growth of *S. maritimus*.

In the Canadian prairies, saline wetlands are generally closed basins where water level changes cause shifts in salinity levels (Millar 1973; Hammer 1978). The relationships among water level, basin volume and salinity are complex and it is difficult to isolate the effects of water level on plant performance in field conditions. As part of a larger study of the ecology of *S. maritimus* var. *paludosus* on the Canadian prairies, a greenhouse experiment was conducted to investigate the effects of water level on the growth and reproduction of this species.

## METHODS

Tubers and rhizomes of *Scirpus maritimus* var. *paludosus* were collected 20 km north of Winnipeg, Manitoba (50°6' N; 97°7' W) in October, 1977 and stored under moist, dark conditions at 4°C for 80 days prior to the experiment. In a rooftop greenhouse, in January, 1978 a circular tank, 2 m in diameter and 70 cm deep, was filled to 60 cm with fresh water (115 micromhos/cm and pH 7.2). Seven plastic pans (36 x 48 x 12 cm) were filled 10 cm deep with sterilized clay-loam soil. Within each pan, six, uniform *S. maritimus* tubers (mean weight 1.6 g) were planted in a regular pattern 12 cm apart and 2 cm deep. The pans were positioned in the tank on wooden stands so that their surfaces were held at depths<sup>2</sup> -50, -40, -30, -20, -10, 0, and +10 cm relative to the water surface. Pans at the 0 and +10 cm levels had holes drilled in the bottom and sides to allow water entry and upward movement by capillary action. To simulate early summer growing conditions, the greenhouse was programmed with 15-hour days at 20°C and 9-hour nights at 16°C. Growing plants were lightly sprinkled with water twice weekly to approximate the 30-year mean frequency of summer rainfall in the mid-Canadian prairies (Canada Department of Environment 1973). At two-day intervals shoot height, floral bud presence and number of tillers were recorded. The above- and below-ground biomass were harvested, washed and dried to a constant weight at 90°C, 68 days after first sprouting. Plants were subdivided into four components: inflorescences; fruiting culms; tillers; and roots, rhizomes and tubers, and weighed.

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<sup>2</sup>-50 cm indicates the soil surface is 50 cm below the water surface, +10 cm indicates the soil surface is 10cm above the water surface.

## RESULTS

Under normal field conditions, buds develop on overwintering tubers. These buds sprout and produce tall, erect shoots (culms) and horizontal rhizomes (Fig. 2-1). Culms usually bear four leaves and terminate in an inflorescence, while the tips of the rhizomes turn upward and produce erect, leafy shoots (tillers). At the base of the tillers new tubers and additional rhizomes are formed.

In our experiment virtually all of the tubers sprouted within six days of planting. Initially, many of the tubers had more than one sprout. At the +10 and 0 cm levels all of the sprouts developed into normal culms. At the -40 and -50cm levels 37 percent of the sprouts aborted before reaching the water surface. However, all levels had at least one sprout per tuber which developed normally.

At the 0 cm level, tiller appearance was 24 days after sprouting and was progressively later at deeper water depths (Fig. 2-2). At the -50 cm level it was 52 days before tillers became evident. The recruitment rate of tillers (tillers/planted tuber/day) was greatest at the +10 cm level. After day 26, the mean recruitment rate was .229 tillers /planted tuber/day. Starting from the +10 cm level, there was a significant decrease ( $p < .05$ ) in the slopes of the tiller recruitment between each of the growing depths. The -50 cm level had a mean recruitment rate of .009 tillers/planted tuber/day.

Generally, culm height increased as water depth increased (Fig. 2-3). At the +10 cm level, culms had a mean height of 83 cm. Culm height showed a linear increase ( $r = -.77$ ) down to

Fig. 2-1 Growth habit of *Scirpus maritimus*.

ot - original tuber  
fc - fruiting culm  
i - inflorescence  
r - rhizome  
vt - vegetative tiller  
nt - new tuber

Fig. 2-2 Mean vegetative tiller recruitment of *Scirpus maritimus* at various water depths.

\* +10 cm indicates soil surface is 10 cm above the water surface.  
-50 cm indicates soil surface is 50 cm below the water surface.  
b = slope or recruitment rate (tillers/planted tuber/day).  
Sb = standard error of the regression coefficient.

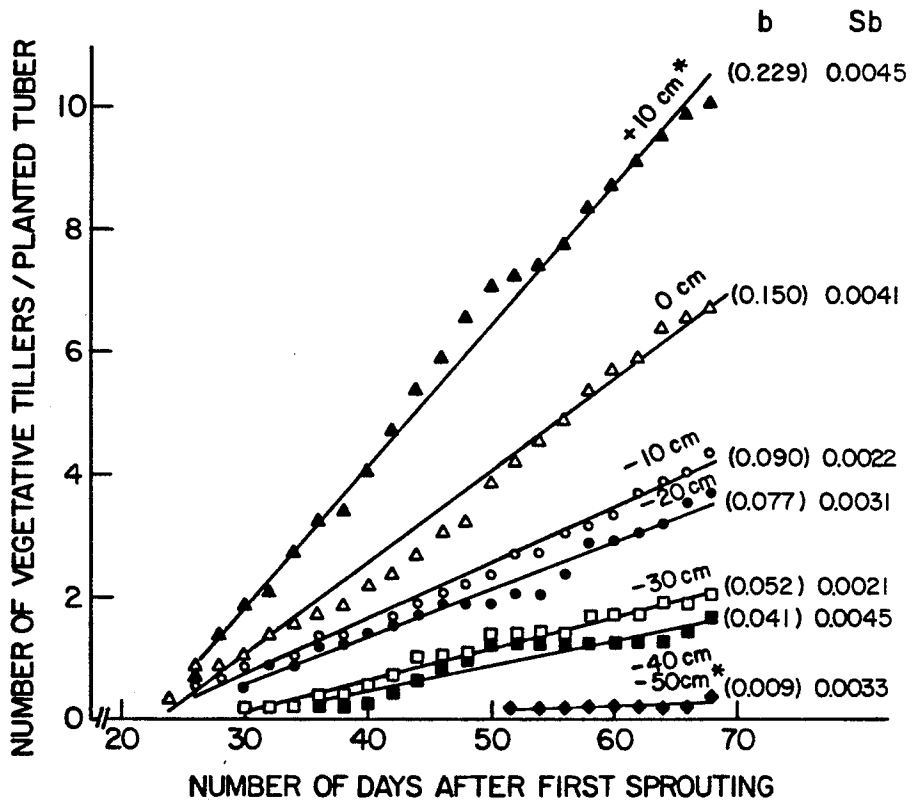
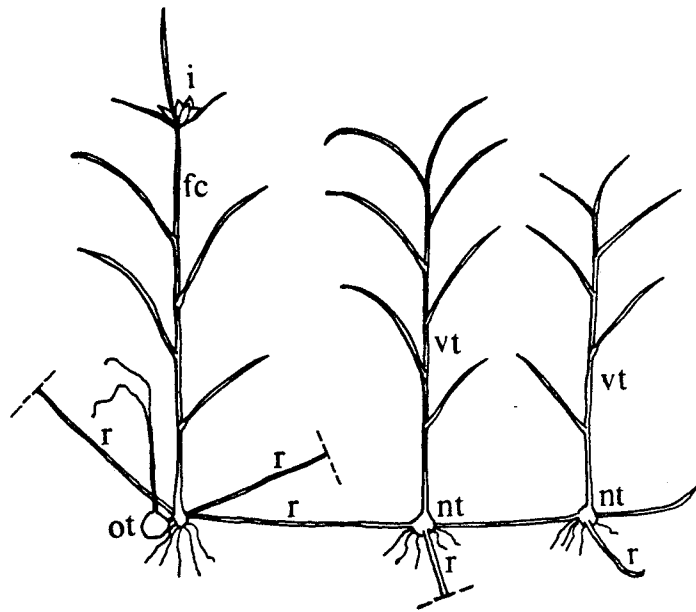
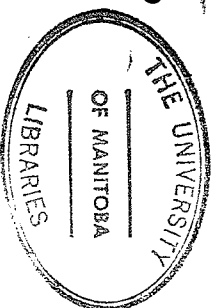
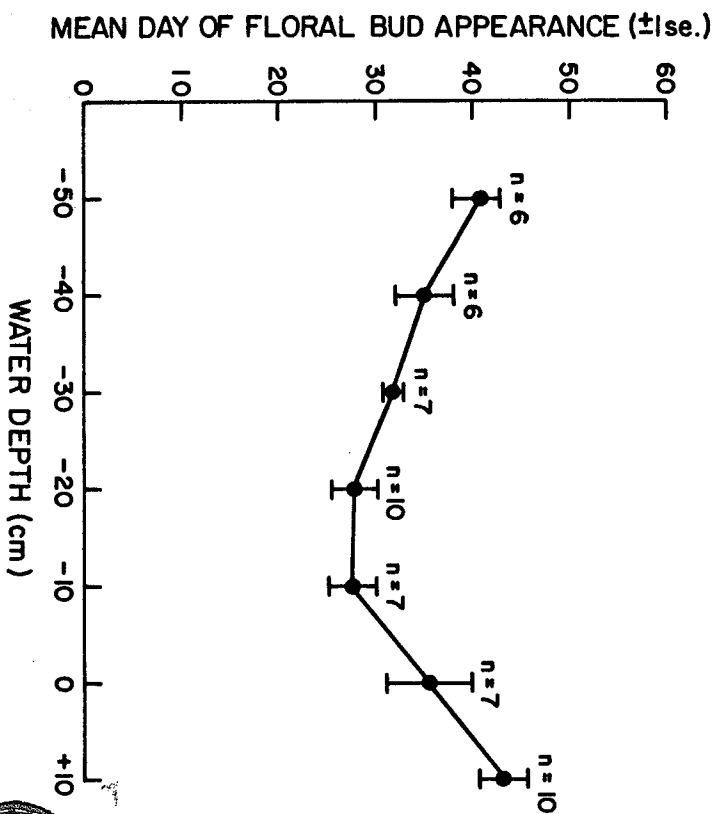
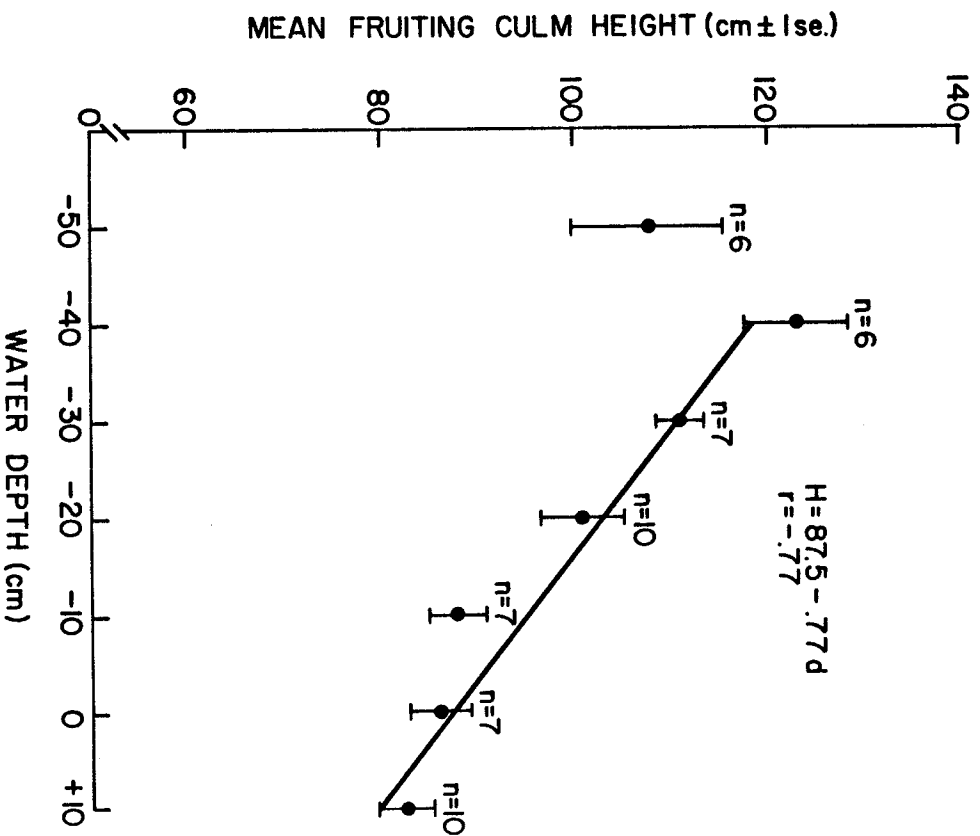


Fig. 2-3 Mean fruiting culm height of *Scirpus maritimus* in relation to water depth.

Fig. 2-4 Mean day of floral bud appearance of *Scirpus maritimus* in relation to water depth.





-40cm, at which the mean height was 123 cm. At the -50 cm level mean height was less than at the -40 cm level but the difference was not significant.

The time of inflorescence was also influenced by water depth (Fig. 2-4). In water 10 cm and 20 cm deep, floral buds appeared 28 days after the sprouting of the planted tubers. Bud development was later ( $p < .01$ ) at the -50 cm level (mean of day 41) and at the +10 cm level (mean of day 43).

The amount and apportioning of biomass were also related to water depth (Fig. 2-5). Vegetative tiller biomass, below-ground biomass and total biomass all showed a significant decrease as water depth increased ( $r = .97, .97, \text{ and } .96$  respectively). Most of the total biomass was made up of vegetative tillers and below-ground portions, except at -50 cm where plants exhibited the least clonal growth and the initial culms accounted for the largest portion of the total biomass.

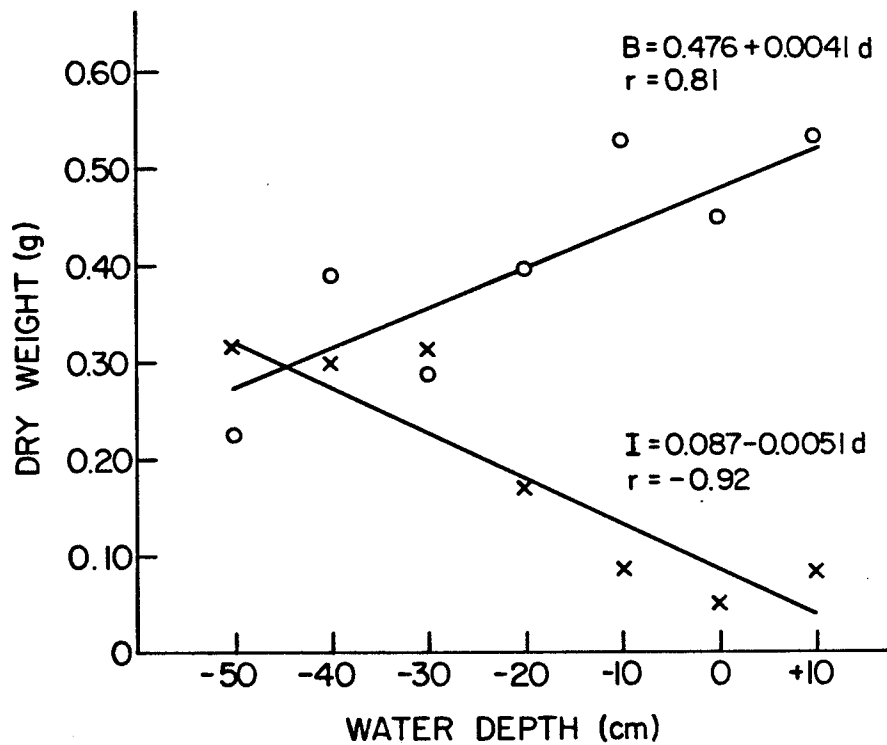
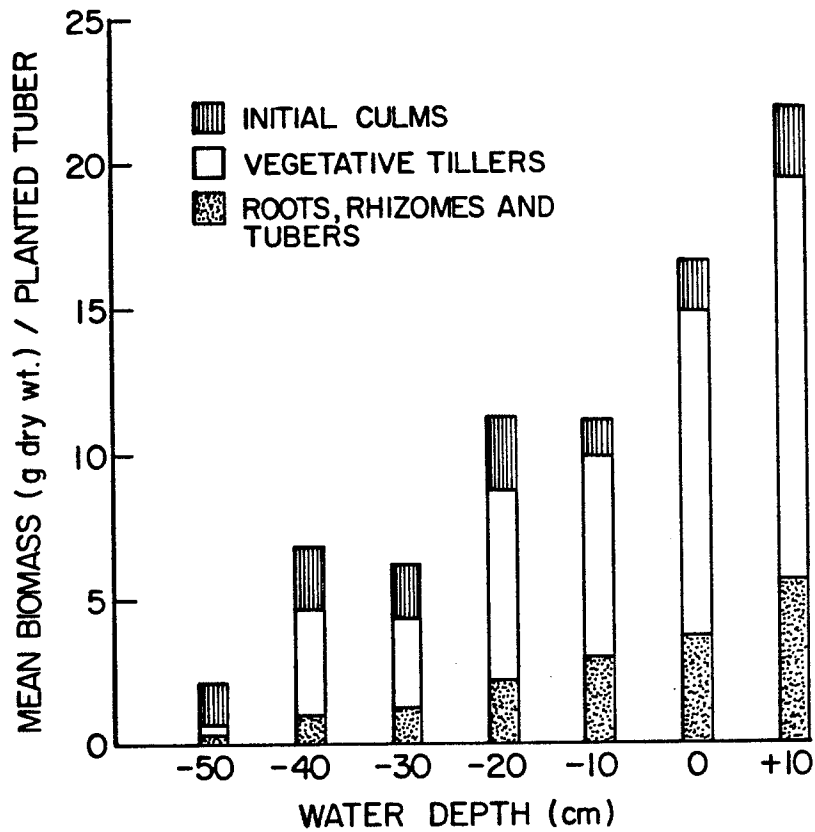
When vegetative and seed reproductive efforts are compared, contrasting trends are evident. Biomass of rhizomes, tubers and roots per stem was reduced in deep water (Fig. 2-6). On the other hand, inflorescence biomass was at a maximum in deep water.

Fig. 2-5 Mean biomass per planted tuber of *Scirpus maritimus* in relation to water depth.

|                      |                                  |
|----------------------|----------------------------------|
| tiller biomass       | $Y = 10.77 + 0.214X$ ; $r = .97$ |
| below-ground biomass | $Y = 4.04 + 0.018X$ ; $r = .97$  |
| total biomass        | $Y = 17.00 + 0.305X$ ; $r = .96$ |

Fig. 2-6 Inflorescence and below-ground biomass of *Scirpus maritimus* in relation to water depth.

I = Mean inflorescence biomass/fruiting culm  
B = Mean below-ground biomass/stem.



## DISCUSSION

Some species shift their reproductive strategies from vegetative to seed production under different environmental conditions (Grime 1979). Sculthorpe (1967) noted that with some submerged species, ie. *Utricularia* spp. or *Myriophyllum verticillatum* L., flowering is reduced in deep water and vegetative reproduction is dominant. Smith (1973) noted the opposite effect with the emergent species *Scolochloa festucacea* where flowering occurs only in those marshes flooded for at least a period in the spring. In our experiment there was a shift from vegetative to seed production with increasing water depth. Plants grown at levels at or above the water surface had greater shoot survivorship and clonal expansion by rhizomes and tillers. In contrast, those in deep water had fewer, but taller shoots, added less total biomass, and invested a higher proportion of biomass in seed production.

In relating these results to field conditions there are several factors to consider. Throughout the growing season in natural sites, *S. maritimus* is generally subjected to falling water levels with corresponding increases in salinity, and rhizome expansion is unrestricted. In our experiment water levels were kept constant and rhizome expansion was restricted by the pan walls. In spite of these differences, height and biomass of the experimental plants were within the ranges found in natural populations and similar growth trends occurred. Our unpublished field data from Saskatchewan show that *S. maritimus* seed production per stem increases at deeper water levels. Clonal growth is optimum at water levels less than

20 cm deep and at depths greater than 30 cm the belowground biomass per stem is reduced.

Increased seed production by *S. maritimus* could be an important survival mechanism when water depth becomes limiting. The Canadian prairies undergo cyclic wet and dry periods which dramatically affect wetland water levels (Millar 1973). Millar (1973) noted that *S. maritimus* disappeared from sites subjected to large increases in water depth probably because this species is not productive in deep water and is out-competed by other emergent species in non-saline conditions (Ungar 1974). Shifting available energy into seed production during conditions of deep and relatively fresh water may promote long term survival. Seeds of *S. maritimus* will float for several days before sinking which enhances their chance of dispersal to new growing sites. Seeds also have a long dormancy period prior to germination (O'Neill 1972) which increases the possibility of their survival during unfavourable periods. During falling water levels, newly-exposed mud flats have been observed to be rapidly colonized by *S. maritimus* seedlings. Once plants are established and shallow conditions prevail, reproduction is mainly by clonal growth.

## CHAPTER 3

DISTRIBUTION AND PRODUCTIVITY OF *Scirpus maritimus* L.  
var. *paludosus* (Nels.) Kük. ON THE CANADIAN PRAIRIES.

## INTRODUCTION

*Scirpus maritimus* L. var. *paludosus* (Nels.) Kük. is the dominant and often the only emergent hydrophyte in the many shallow saline wetlands on the Canadian prairies. Previous work discussing some of the aspects of the ecology of saline wetlands in the northern prairies (Dodd and Coupland 1966; Walker and Coupland 1970; Stewart and Kantrud 1972) considers *S. maritimus* to have a wide tolerance to environmental conditions and to occupy the shallow, sometimes dry zone around saline wetlands. Ungar (1974) notes that *S. maritimus* is usually found in monospecific stands in wetlands with salinities from 0.7 to 4.6%. It shows a drop in stem weight and height with increasing salinity (Kaushik 1963) and is out-competed by other emergents in fresh conditions. Millar (1973) and Dykyjova (1973) observe that there is a decrease in *S. maritimus* stem density in water 80-90 cm deep. Aspects of *S. maritimus* reproductive strategies in relation to water depth are discussed by Lieffers and Shay (1981b). No published work has considered the simultaneous effects of water depth and salinity under field conditions on the productivity of this species.

General limnological and hydrological features of some of the saline lakes in the Canadian prairies are discussed by Rawson and Moore (1944), Roskowska and Roskowski (1969), Hammer (1978), Hammer and Haynes (1978) and Lieffers and Shay (1981d). These shallow lakes, which usually terminate drainage systems,



change, from spring to fall, from conditions of high water levels and low salinity to low water levels and high salinity. Besides seasonal variability, the 5-20 year climatic cycles of the prairie regions (Millar 1973; van der Valk and Davis 1978) cause variability in wetland water depth and salinity between years.

This paper is one of a series concerned with the distribution, ecology and productivity of *Scirpus maritimus* in the Canadian Prairies. This paper aims to describe:

- 1) the distribution of *S. maritimus* in the Canadian prairies;
- 2) how water levels and salinity affect *S. maritimus* biomass production and its allocation, and association with other species;
- 3) how biotic and other environmental factors influence *S. maritimus* growth.

#### Description of Study Area

The main field study centred on the prairie and parkland regions of the Canadian prairies. Elevation of the region is from 500 to 900 m above sea level. Bedrock is mainly sedimentary (shale, sandstone and conglomerates) from the Upper Cretaceous, with unconsolidated surface material of glacial origin (National Atlas of Canada 1972).

Climate (according to the Thornthwaite scheme) ranges from subhumid in southern Manitoba to subarid in southern Alberta, with a mean precipitation of 46 to 36 cm from east to west. The majority of this precipitation falls from April to July, and the region has from 100 to 120 frost-free days from late May to early September (Weir and Matthews 1971).

Spring temperatures in 1979 were unusually low over most of the prairie region. Weather stations at Medicine Hat, Alberta; Saskatoon, Saskatchewan; and Brandon, Manitoba had respectively, mean temperatures for April 2.5, 5.2, and 4.9° C and for May 1.5, 1.3 and 2.2° C, all below the 30 year mean (Canada Dept. of Fish. and the Environment). Temperatures throughout the region were slightly above normal for June and July.

Study wetlands ranged from 3.3 to 3995 ha and most had a maximum recorded depth of less than 1.0 m (Table 3-1). Generally, these wetlands are closed drainage basins, but in some, water outflow can occur in very high water years. Mineral sediment textures ranged from clay to very fine sand and were often overlain by shallow (< 10 cm) organic horizons. In late May, the water  $\text{Na}^+/\text{Mg}^{++}$  ratio (meq) ranged from 0.5 to 5.8, and  $\text{SO}_4^-$  was the dominant anion in all the sites examined. Depending upon the season and the year, water levels in many of the study sites fluctuated as much as 1.03 m. Corresponding with these water level changes, many of the wetlands changed salinity categories (Millar 1976) from moderately saline (2-15 mmhos/cm) to saline (15-45 mmhos/cm) and some to hypersaline (> 45 mmhos/cm) during the study period (Table 3-1).

#### METHODS

The distribution of *S. maritimus* was determined from specimens from the major herbaria in the prairie provinces (Universities of Manitoba, Saskatchewan, Alberta and Calgary) and from the National Herbarium and the Biosystematics Research

Table 3-1 Physical and chemical features of *Scirpus maritimus* study sites, 1978 and 1979.

| Site No. | Lat. N | Long. W | Area (ha) | Maximum Basin Depth <sup>1</sup> |             | Water Conductivity (mmhos/cm) | Na <sup>+</sup> /Mg <sup>++</sup> <sup>2</sup> |                 | Basin <sup>3</sup> Type | Sediment <sup>4</sup> Texture |
|----------|--------|---------|-----------|----------------------------------|-------------|-------------------------------|--|-----------------|-------------------------|-------------------------------|
|          |        |         |           | Depth (cm)                       | Range (cm)  |                               | Mg <sup>++</sup>                               | Na <sup>+</sup> |                         |                               |
| 1        | 49°20' | 112°11' | 145       | >66                              | -60 to -28  | 1.0 to 3.7                    | 2.5  | c               | C                       |                               |
| 2        | 49°13' | 111°58' | 770       | >103                             | -103 to -86 | 0.8 to 1.3                    | 2.9  | o               | L                       |                               |
| 3        | 50°18' | 107°39' | 4.2       | 40                               | -30 to -14  | 3.2 to 21.6                   | 0.5  | c               | L                       |                               |
| 4        | 50°25' | 107°12' | 10        | 55                               | -29 to 20   | 2.3 to 39.1                   | 4.4  | c               | C                       |                               |
| 5        | 50°24' | 106°59' | 3550      | >100                             | -14 to 9    | 4.8 to 11.7                   | 2.0  | c               | C                       |                               |
| 6        | 50°27' | 106°44' | 29        | 40                               | -46 to 12   | 7.4 to 50.5                   | 2.5  | c               | C                       |                               |
| 7        | 50°27' | 106°43' | 12        | 40                               | -26 to 10   | 2.9 to 7.9                    | 2.7  | o               | C                       |                               |
| 8        | 51°46' | 107°26' | 3995      | >100                             | 0 to 50     | 4.4 to 26.8                   | 2.5  | c               | VFS                     |                               |
| 9        | 51°49' | 106°31' | 54        | 60                               | -19 to 17   | 6.3 to 24.4                   | 2.6  | o               | L                       |                               |
| 10       | 51°42' | 106°32' | 306       | 100                              | -17 to 61   | 2.3 to 9.3                    | 1.0  | o               | L                       |                               |
| 11       | 51°50' | 106°30' | 3.9       | 75                               | -45 to 0    | 1.9 to 54.0                   | 2.4  | c               | CL                      |                               |
| 12       | 52°02' | 106°18' | 8.6       | 65                               | -45 to 14   | 1.4 to 30.8                   | 0.6  | c               | CL                      |                               |
| 13       | 52°11' | 106°17' | 220       | 60                               | -34 to 23   | 3.1 to 26.8                   | 1.4  | c               | CL                      |                               |
| 14       | 52°00' | 106°10' | 101       | 80                               | -62 to -9   | 1.1 to 32.5                   | 5.6  | c               | C                       |                               |
| 15       | 51°53' | 106°14' | 3.3       | 85                               | -24 to 0    | 1.8 to 6.7                    | 0.5  | c               | L                       |                               |
| 16       | 51°51' | 105°52' | 92        | 80                               | -68 to 21   | 4.4 to 41.3                   | 3.3  | c               | C                       |                               |
| 17       | 51°59' | 105°58' | 9.3       | 70                               | -50 to 53   | 0.8 to 18.9                   | 3.2  | c               | L                       |                               |
| 18       | 52°12' | 105°11' | 22        | 80                               | -36 to 10   | 1.7 to 14.1                   | 1.0  | c               | CL                      |                               |
| 19       | 51°48' | 105°46' | 12        | 60                               | -35 to 5    | 3.8 to 16.2                   | 5.8  | o               | L                       |                               |
| 20       | 51°47' | 105°44' | 91        | 66                               | -38 to 10   | 4.4 to 39.2                   | 2.7  | o               | L                       |                               |
| 21       | 51°46' | 104°33' | 40        | 72                               | -44 to 4    | 1.1 to 25.8                   | 1.7  | o               | L                       |                               |
| 22       | 51°43' | 104°36' | 7.8       | 50                               | -35 to 9    | 1.7 to 28.3                   | 1.2  | c               | C                       |                               |
| 23       | 50°26' | 100°22' | 31        | 40                               | -26 to 17   | 4.8 to 58.0                   | 3.0  | c               | C                       |                               |
| 24       | 52°25' | 100°19' | 9.8       | 65                               | -46 to 12   | 3.4 to 31.1                   | 2.8  | c               | C                       |                               |

<sup>1</sup>Water depth range (mid *S. maritimus* stand).

<sup>2</sup>Water Na<sup>+</sup> (meq/l)/Mg<sup>++</sup> (meq/l) for the end of May 1979.

<sup>3</sup>c = closed basin; o = open basin, outflow possible in high water years.

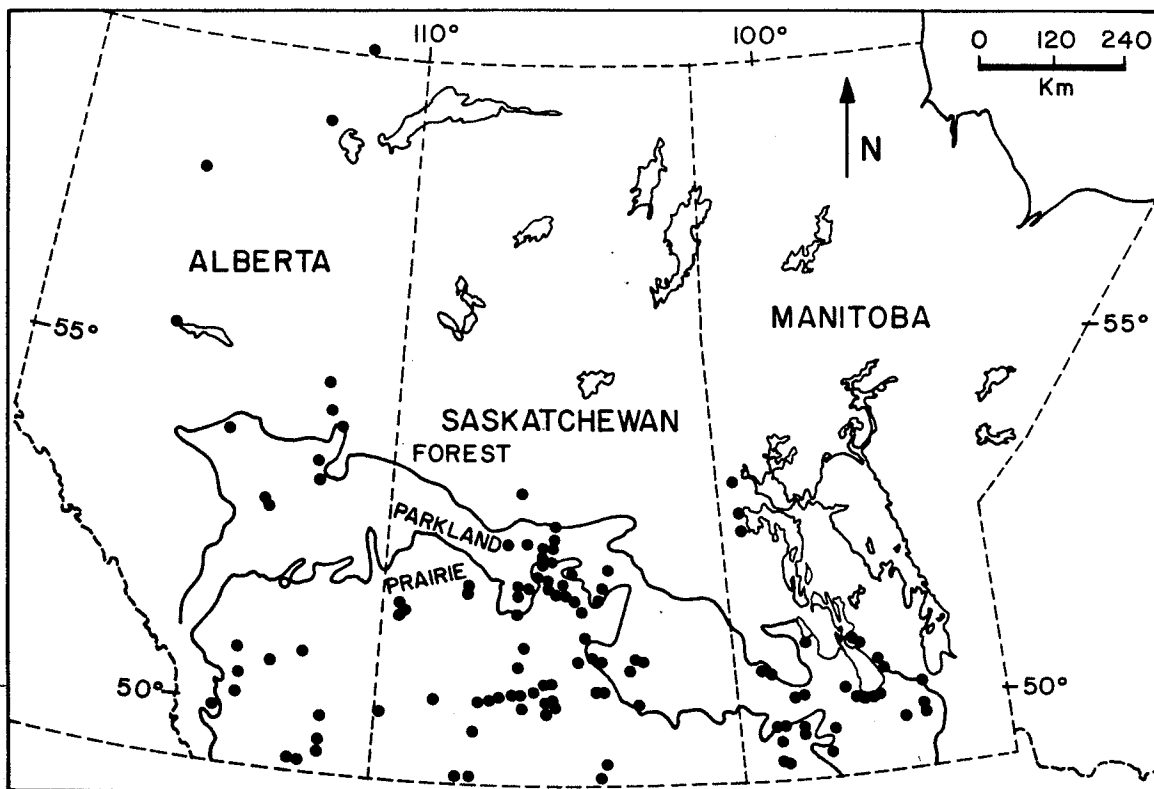
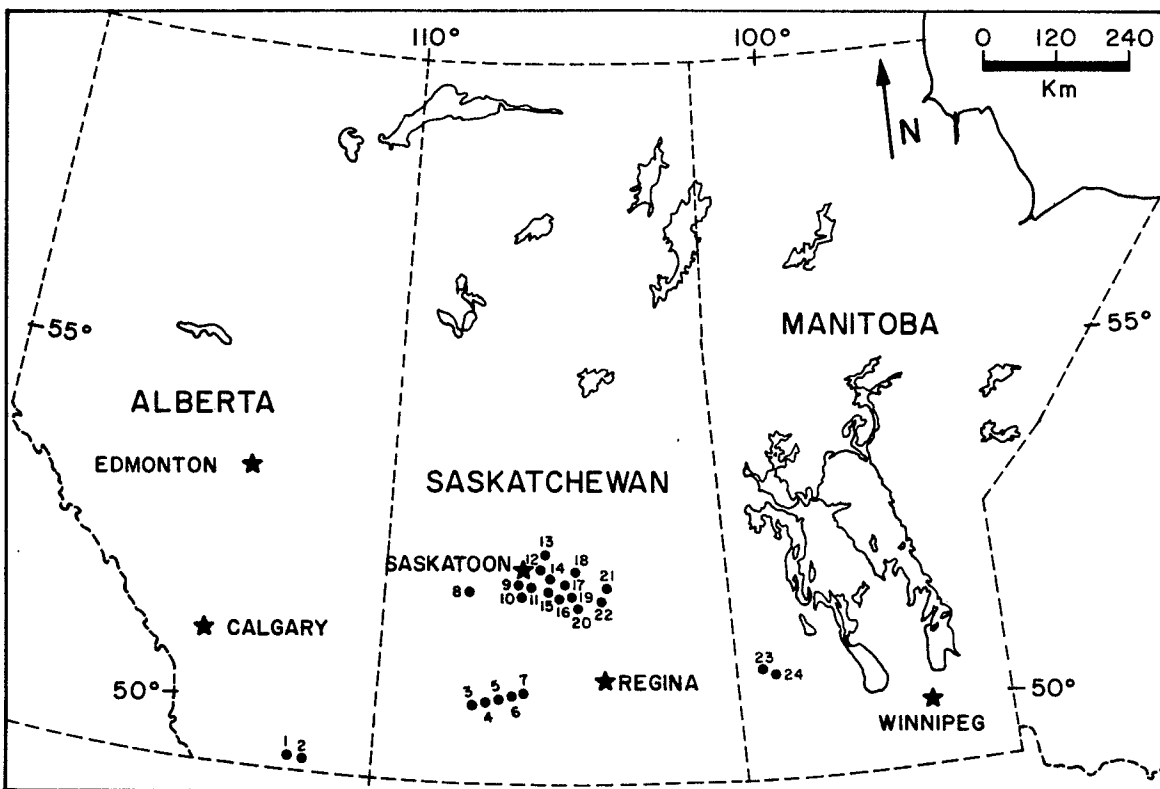
<sup>4</sup>Sediment texture (mid *S. maritimus* stand), (Manitoba Provincial Soil Testing Laboratory). C clay; L loam; VFS very fine sand.

Institute, Ottawa. Additional sites were recorded during the field study. Voucher specimens are deposited in the University of Manitoba Herbarium. Taxonomy is according to Scoggan (1978).

In 1977 most of the study sites were identified, numbered (Fig. 3-1) and their water levels and water conductivity recorded. The criteria for the selection of the sites were that the *S. maritimus* stand have a minimum area greater than 30 x 30 m. and that the sites covered a wide range of salinity types. In 1978, each of the 24 sites was sampled at monthly intervals during the summer. At the first sampling period, in early May, rain and water level gauges were established and the elevation contours of the shoreline within the *S. maritimus* zone were estimated by measuring the water depth. If dry at the time, a surveyors level and rod were used. A sediment sampling station was selected and marked in the middle of the *S. maritimus* zone. At each sampling period the water level gauge was measured and rainfall recorded. Phenological information and factors affecting *S. maritimus* growth were noted. Sediment cores (10 cm in diameter) were extracted from the surface sediments at the sampling stations. The core was drained for 30 seconds and the top 10 cm was retained and air-dried. Water samples were collected from 15 cm below the water surface. Alkalinity was measured at the time of collection by titration with 0.1N H<sub>2</sub>SO<sub>4</sub> (APHA 1971) and pH with a Fisher model 150 pH meter. Two portions of the sample were filtered, the first was acidified with 1.0 ml

Fig. 3-1 *Scirpus maritimus* study sites in the Canadian prairies.

Fig. 3-2 Herbarium records for *Scirpus maritimus* in the Canadian prairies.



of 4N H<sub>2</sub>SO<sub>4</sub> per 100 ml sample and the second frozen. Specific conductance was measured on an unfiltered portion of the sample using a Radiometer CDM2e conductivity meter standardized at 25<sup>o</sup> C. Conductivity is a good measure of total dissolved solids (Appendix II).

At the late August sampling period 10 quadrats (0.25m<sup>2</sup>) within the *S. maritimus* zone, were chosen by coordinates from a random number table. Within each quadrat the water depth, mean plant height (the distance from the sediment to the top of the tallest leaf or bract), fruiting culm and non-fruiting stem number, percent litter cover and the percent aerial cover by competitive species were recorded. The fruiting culms and non-fruiting stems were clipped at ground level and collected in separate paper bags. Below-ground biomass was collected from a 0.0625m<sup>2</sup> quadrat nested in the upper right corner of the 0.25m<sup>2</sup> quadrat. Samples were washed and the roots, rhizomes and tubers produced during the current growing season collected. Tubers were counted and subsequently, during data analysis, each tuber was considered to have had one aerial stem.

It was determined from concurrent work (Lieffers and Shay 1980d) that the single sediment sample in the middle of the stand did not accurately represent the salinity at other elevations on the basin slope. Therefore in 1979, three sampling stations were established within the *S. maritimus* zone; at the outer perimeter, the middle of the zone, and the inner perimeter. In late August, at each of

the three sediment sampling stations, three randomly distributed quadrats were harvested along a transect running through the sampling station and parallel to the shoreline. Other aspects were similar to 1978 but the sites in Alberta were omitted because of time constraints.

#### Laboratory Analysis

Air-dried sediments were ground with a mortar and pestle. Saturated paste extracts of the sediments (McKeague 1976) were tested for pH, alkalinity and specific conductance as previously described. Chloride concentrations for both the sediment extracts and the frozen water sample were determined by titration with mercuric nitrate using a diphenylcarbazone indicator (Stainton et al. 1977). Sulfate determinations were made by the barium chloride turbidimetric technique (APHA 1971). A Perkin-Elmer 403 atomic absorption spectrophotometer and the techniques outlined in its manual were used to assay sodium, magnesium, calcium and potassium ion concentrations.

Plant biomass was dried to a constant weight at 90°C and the fruiting culms, inflorescences, non-fruiting stems and below-ground portions weighed.

#### Data Analysis

The large seasonal changes in water levels and concomitant changes in conductivity prompted us to characterize each sampling station by using the mean water level and mean conductivity. Means were calculated for both water level and conductivity for each of the four periods, early May to late May, early May to late June, early May to late July and



early May to late August. As most of the study sites were dry during the fall and flooded during the summer there was usually a marked difference between the water and sediment salinities during the early part of the growing season. When reflooded, the sediments generally contained more salts than the water. In these situations there was a good correlation between water conductivity and *S. maritimus* growth. When dry, the sediment conductivity was the only salinity measure available. Depending upon the site condition, (whether flooded or dry) the mean conductivity of each sampling station might be made up of water or sediment conductivity values or both. With stations flooded for a period in the spring and dry later in the summer, a combination of water conductivity and later sediment conductivity were used to calculate the mean conductivity. The latter was transformed to natural logarithms ( $\ln$ ) to form linear relationships with *S. maritimus* growth.

As the above-ground quadrat size was different from the below-ground quadrat the below- to above-ground biomass ratio was calculated by dividing the mean below-ground weight per stem by the mean above-ground weight per stem within the same quadrat.

Multiple regression analysis, with variable selection by forward and backward stepping (Dixon and Brown 1977) was used to test for significance of the variables; mean water depth and  $\ln$  of the mean conductivities of the four time

periods, percent litter cover, percent cover of associated species, basin size and maximum depth, sediment texture and the ion ratio of the major soluble salts. Generally, since only the mean water depth and conductivity explained a large proportion of the variance in *S. maritimus* growth, further analysis centred on these variables. Only the three quadrats closest to the single sediment sampling station in 1978 were included in the data set. The 1978 and 1979 data were analyzed separately but since there were no significant differences between the slopes and intercepts of the regression equations for the two years, the data were combined. The 1978 data from site no. 2 were excluded from the analysis as the mean depth was 40 cm deeper than at any other site. Generally, only the mean water depth and salinity were used in the final regression equation. The generalized regression is:

$$Y = B_0 + B_1 X + B_2 \ln Z \quad (1)$$

where:  $Y$  = a measure of *S. maritimus* performance,

$X$  = mean water depth,

$Z$  = mean conductivity.

Some of the regressions fitted a second or third degree polynomial for mean water depth.

## RESULTS

Distribution of *S. maritimus* (Fig. 3-2) in the Canadian prairies is clustered on soils of high salinity or in regions of internal drainage, outlined for Saskatchewan by Richards and Fung (1969). Most of the collections were from the prairie and parkland areas; however a few were made in the boreal forest.

Within the saline wetlands themselves, the distribution and range of the *S. maritimus* zone depends upon the basin morphology and salinity of the wetland. Hypersaline wetlands (salinity categories of Millar 1976) have *S. maritimus* in a narrow band on the upper part of the basin (Fig. 3-3), leaving a large open water central area (eg. sites no.6 and 23). The saline wetland category has *S. maritimus* over a broad band of the upper and mid-slope of the basin. Most of the study sites fall into this category. Moderately saline wetlands contain monotypic stands of *S. maritimus* near the centre during periods of low water level; at the more usual higher water levels and lower salinities other emergents dominate the higher zones of the shoreline.

When flooded *S. maritimus* usually grows in monospecific stands in saline and hypersaline wetlands. In some of the saline and moderately saline sites *Scirpus lacustris* L. ssp. *glaucus*<sup>2</sup> (Sm.) Hartm. and *S. lacustris* L. ssp. *validus*<sup>3</sup> (Vahl) Koyama, *Typha latifolia* L. and *Eleocharis palustris* (L.) R. and S. are also present but usually distinctly separated from the *S. maritimus* stands. *Triglochin maritima* L. is often found intermixed with *S. maritimus*, particularly in shallow zones.

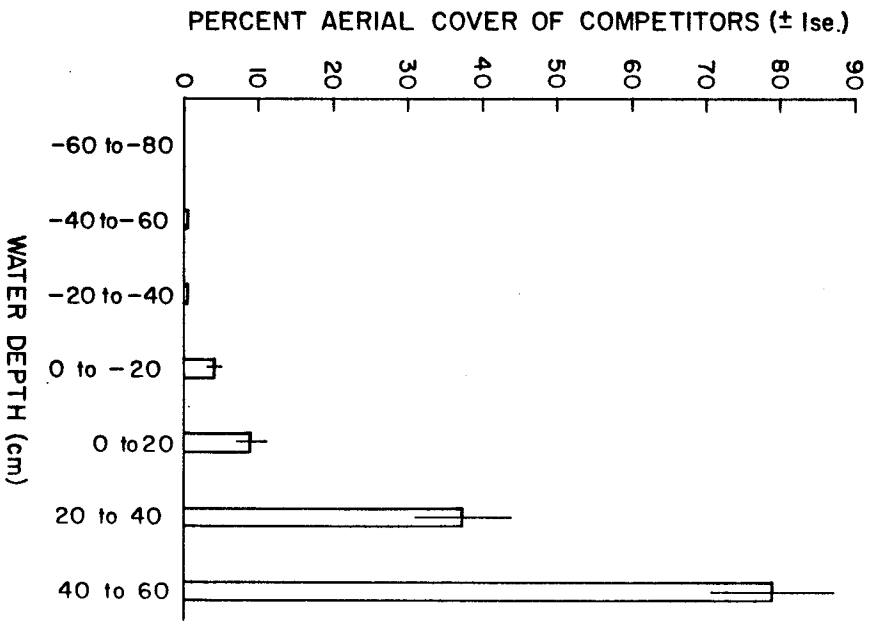
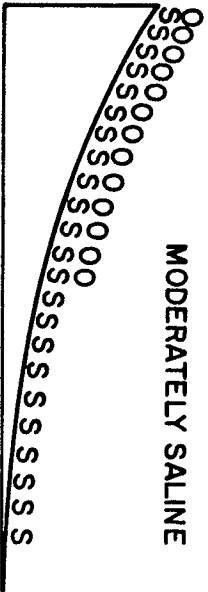
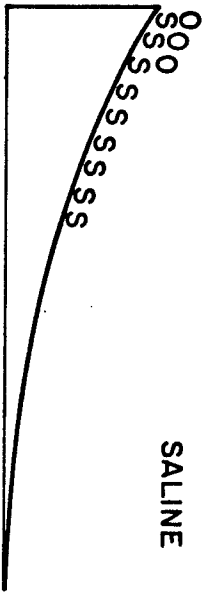
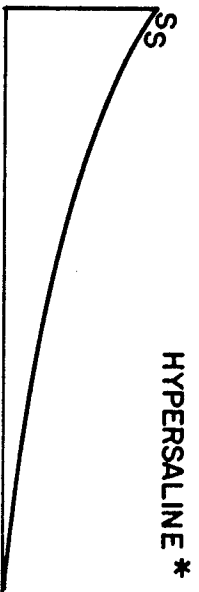
Formerly *Scirpus acutus*<sup>2</sup> Muhl. and *S. validus*<sup>3</sup> Vahl (according to Koyama 1962)

Fig. 3-3 Potential distribution of *Scirpus maritimus* (S) and other emergent species (O) on the basin profile of three saline lake types.

\* Salinity categories of Millar (1976).

Fig. 3-4 Mean percent aerial cover of species associated with *Scirpus maritimus* stands in relation to water depth in late June.

-60 indicates that the soil surface is 60 cm below the lake water level.



Within portions of *S. maritimus* stands flooded for most of the season, *Potamogeton pectinatus* L., *Zannichellia palustris* L., *Enteromorpha* sp. and *Chara* spp. are often abundant. Occasionally, due to wave action, floating mats of *Enteromorpha* and uprooted *P. pectinatus* build up at the periphery of the *S. maritimus* stands and flatten the *Scirpus* stems.

When saline lakes dry out, *S. maritimus* stands are quickly invaded by *Atriplex patula* L., *Suaeda maritima* (L.) Dumort., *Chenopodium rubrum* L., *Salicornia europaea* L. ssp. *rubra* (Nels.) Breitung and *Hordeum jubatum* L. (Fig. 3-4). This invasion was also noted by Dodd and Coupland (1966). When reflooded the mudflat wet meadow species are quickly killed off and *S. maritimus* regains dominance.

Seed germination was observed at some period during the study at virtually all 24 sites. Germination occurred on wet mudflats or in shallow water (<5 cm) and with sediment conductivities up to 20 mmhos/cm. Kaushik (1963) reported reduced *S. maritimus* germination at 1.5% NaCl salinity ( $\approx$ 15 mmhos/cm). In 1978, at site no. 8, seeds germinated over a 100m wide band of wet mudflat that had been exposed by receding water levels. In late June, at the time of germination, sediment conductivity was 12-18 mmhos/cm and by August, after a further water level drop, sediment conductivity in the seedling area, was 35 mmhos/cm. By 1979, the area was covered by a dense, healthy stand of *S. maritimus*.

The step-wise multiple regression analysis indicated that for the sites and years examined, differences in basin size and maximum depth, sediment texture, percent litter

cover by associated species or the ionic ratio of the major soluble salts (latter also noted by Ungar (1970)) did not explain a large part of the variance in *S. maritimus* growth and productivity.

Most of the measures of *S. maritimus* performance had the best correlations with the sampling station mean water depth and salinity, both averaged from early May to the end of July. The mean conductivities and water depths of the 89 sampling stations in the data set (considering the three sampling stations of the 22 sites in 1979 and the one station of the 23 sites in 1978) range from 1.0 to 55 mmhos/cm conductivity and from +40 to -65 cm deep<sup>4</sup> (Fig. 3-5). This is the valid range of the regression equations. In dry sites conductivities were always high while in sites with deep water conductivities were low. The pattern of the data (Fig. 3-5) must be considered to note where the following regression equations extrapolate into areas of the graph not covered by the data (e.g. Fig. 3-6).

#### Plant Height

Mean plant height of *S. maritimus* within the quadrats ranged from 8-140 cm with a mean of 78 cm for all of the quadrats. Regression analysis on plant height had an  $R^2$  of 86.6% using a third degree polynomial of the mean water depth and the  $\ln$  of the mean conductivity averaged to the end of July (Fig. 3-6). The increase in plant height was sigmoidal in relation to increasing mean water depth. The curve levels

<sup>4</sup>+40 cm indicates the sediment surface is 40 cm above the lake water surface. -65 cm indicates the sediment surface is 65 cm below the lake water surface.

Fig. 3-5 Mean water depth and conductivity of the *Scirpus maritimus* sampling stations, 1978 and 1979 (averaged to the end of July).

-70 indicates that the soil surface is 70 cm below the lake water surface.

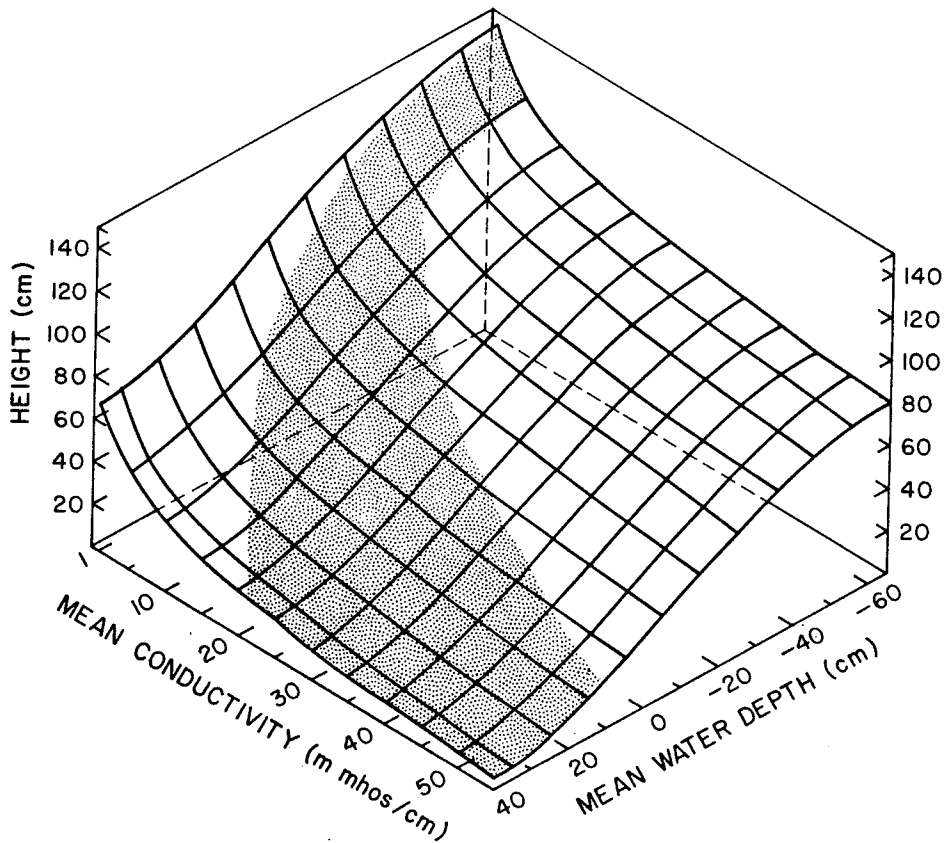
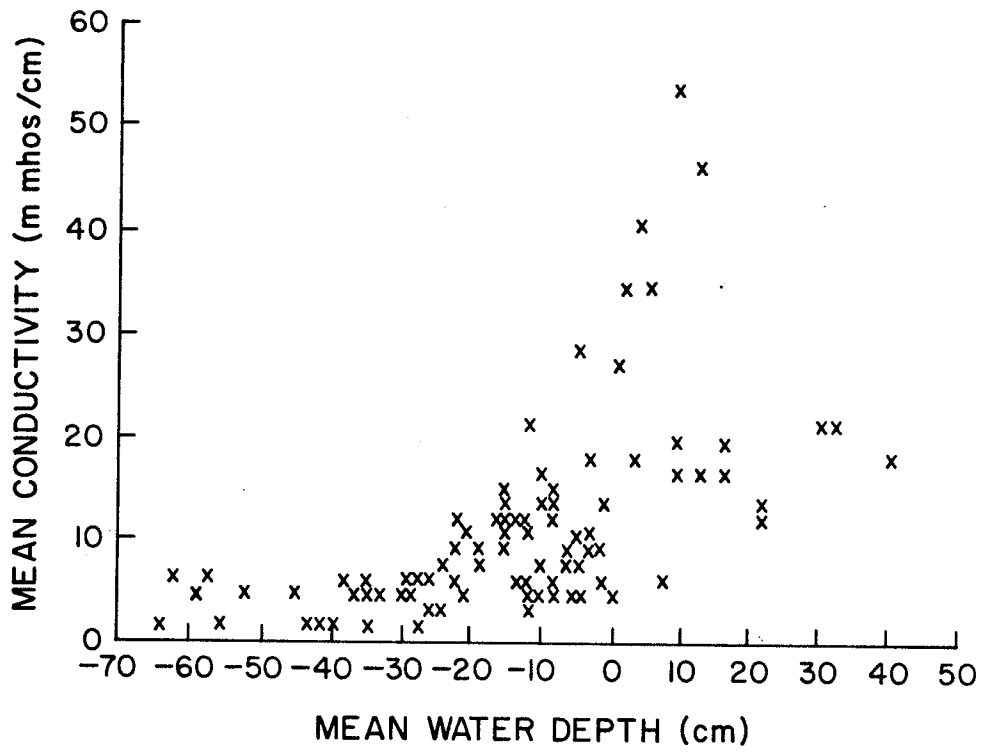
Fig. 3-6 Mean height of *Scirpus maritimus* in relation to the mean water depth and conductivity (averaged to the end of July).

$$Y = 97.49 - 0.9965X + 0.00306X^2 + 0.00011X^3 - 16.064 \ln Z$$

$$R^2 = .886 \quad S_y = 11.19 \quad F = 563$$

Shaded area indicates the approximate range of the data set.





off in dry conditions and in deep water (-65 cm). Plants between 130 and 140 cm tall were observed in a site, not included in the study, where the mean water depth was -100 cm, suggesting that the upper plateau of the graph could be extended horizontally into deeper water. In water deeper than -60 cm stems were weak and developed necrotic tissue at their bases.

#### Stem Weight

Regressions on the mean weight per stem (Fig. 3-7) and the mean weight per flowering culm (Fig. 3-8) fitted the third degree polynomial of the mean depth and the  $\ln$  mean conductivity (averaged to the end of July), with an  $R^2$  of 68.0% for mean weight per stem and an  $R^2$  of 60.0% for the mean weight per flowering culm. Mean weight per stem ranged from 0.07 to 3.45 g with an overall mean of 1.5 g. Mean weight per flowering culm ranged from 0.35 to 4.77 g with an overall mean of 2.1 g. Even though non-flowering culms are usually as tall as flowering culms and have six or more leaves instead of the normal four for flowering culms, the large spikelets and stalks result in flowering culms being substantially heavier.

#### Stem Density

Density in quadrats ranged from 4 to 440 stems/m<sup>2</sup> with an overall mean of 232 stems/m<sup>2</sup>. A third degree polynomial regression on the mean water depth and the  $\ln$  of the mean conductivity to the end of June was fitted ( $R^2=36.0\%$ ) with stem density (Fig. 3-9). Peak stem density occurred at a mean depth of -30 cm and density decreased slightly at higher salinities.

Fig. 3-7 Mean weight per stem of *Scirpus maritimus* in relation to mean water depth and conductivity (averaged to the end of July).

$$Y = 2.04 - 0.0222X + 0.0000504X^2 + 0.00000227X^3 - 0.384 \ln Z$$

$$R^2 = .680 \quad S_y = 0.441 \quad F = 182$$

Fig. 3-8 Mean weight per flowering culm of *Scirpus maritimus* in relation to the mean water depth and conductivity (averaged to the end of July).

$$Y = 2.026 - 0.0308X + 0.000345X^2 + 0.00000598X^3 - 0.283 \ln Z$$

$$R^2 = .604 \quad S_y = 0.62 \quad F = 108$$

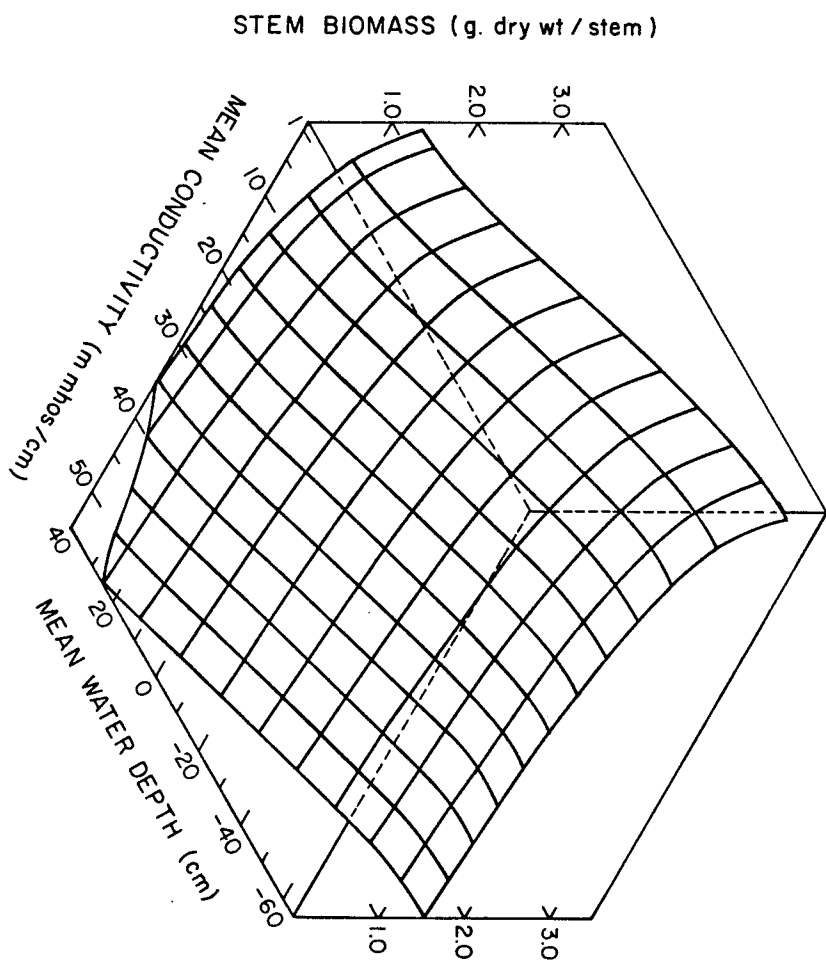
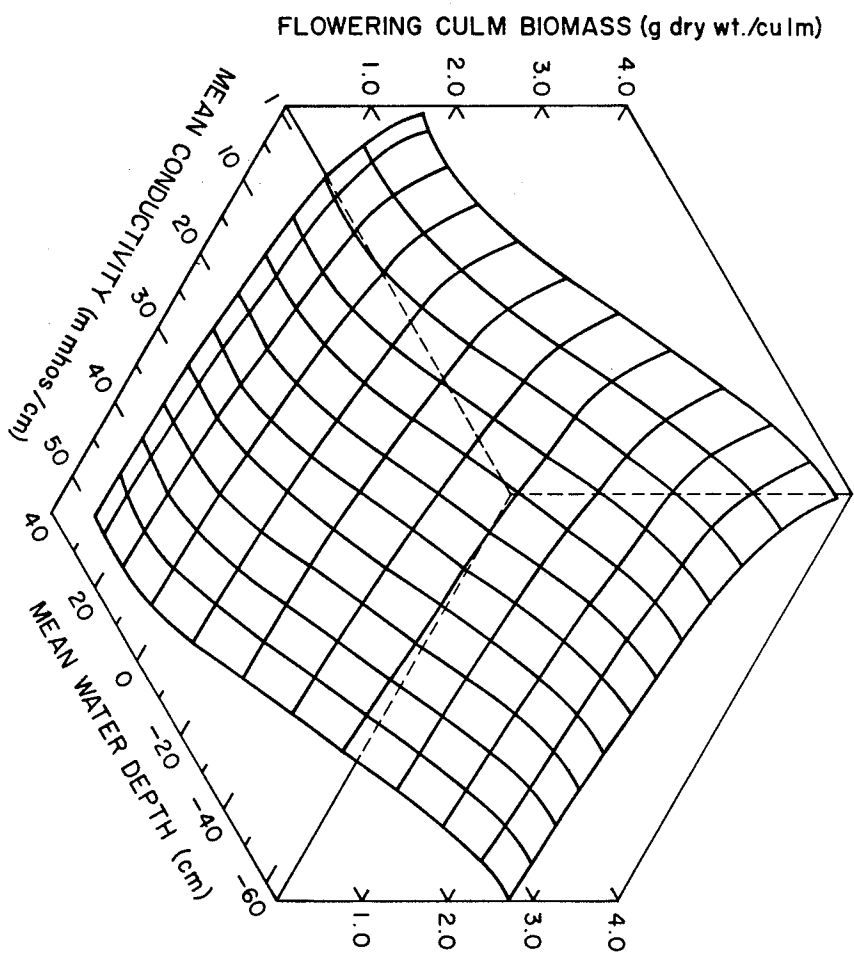


Fig. 3-9 Mean stem density of *Scirpus maritimus* in relation to the mean water depth and conductivity (averaged to the end of June).

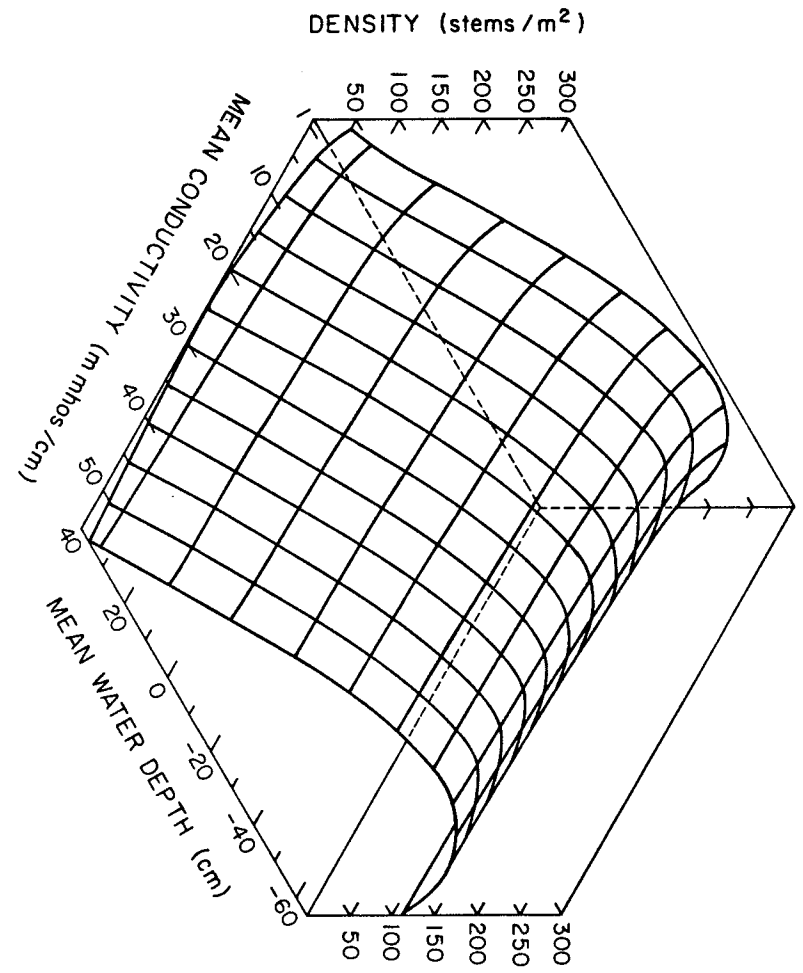
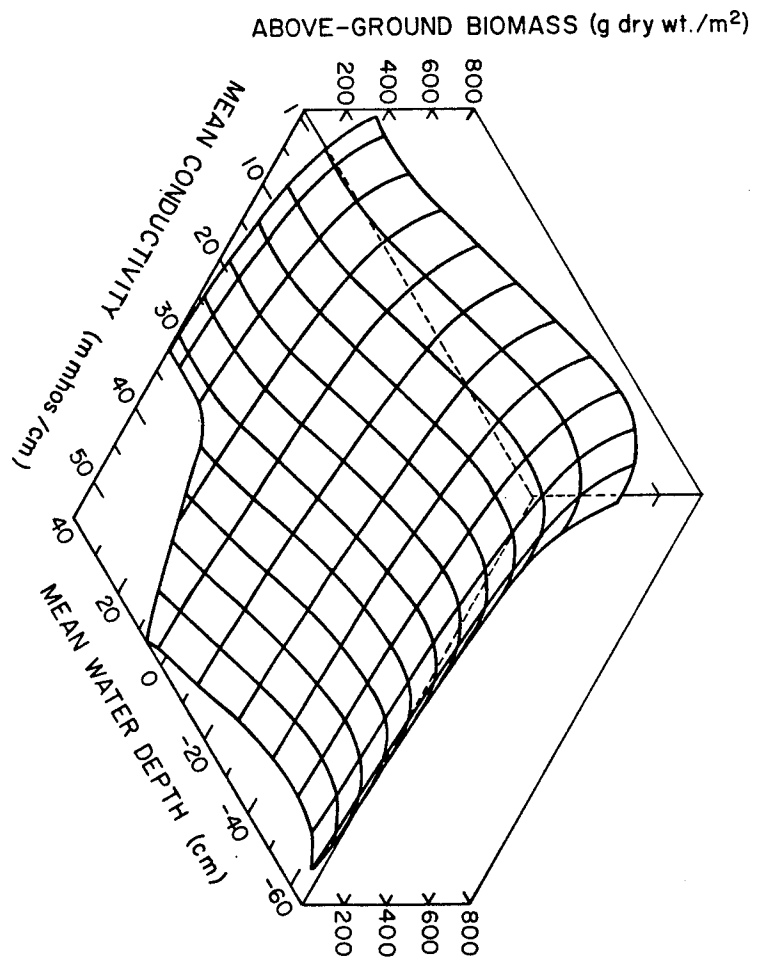
$$Y = 232.3 - 4.044X - 0.0422X^2 + 0.00056X^3 - 12.50 \ln Z$$

$$R^2 = .360 \quad S_y = 72.20 \quad F = 48$$

Fig. 3-10 Mean above-ground biomass of *Scirpus maritimus* in relation to the mean water depth and conductivity (averaged to the end of July).

$$Y = 523.0 - 8.614X + 0.0229X^2 + 0.00278X^3 - 109.5 \ln Z$$

$$R^2 = .648 \quad S_y = 124.1 \quad F = 155$$



### Above-ground Standing Crop

The *S. maritimus* peak above-ground standing crop in individual quadrats ranged from 3.2 to 936 g/m<sup>2</sup> with an overall mean of 361 g/m<sup>2</sup>. Regression analysis fitting the third degree polynomial of the mean water depth and the *ln* of the mean conductivity, averaged to the end of July ( $R^2=64.8\%$ ) was used to account for part of the variance in above-ground standing crop (Fig. 3-10). Peak standing crop occurred at a depth of -35 cm.

Marked changes in above-ground standing crop from one year to the next were recorded during the study. As an example, site no. 23, with a mean water depth of +9 cm and a mean conductivity of 54 mmhos/cm in 1978 had a peak above-ground standing crop of 21 g/m<sup>2</sup>. With the deeper water levels (-16 cm) and reduced salinity (12.3 mmhos/cm) in 1979, peak above-ground biomass was 386 g/m<sup>2</sup>, an 18-fold increase in a single year.

### Below-ground Growth

Third degree polynomial regressions of the mean water depth and the *ln* of the mean conductivity, averaged to the end of July, were fitted to the mean annual below-ground weight per stem (Fig. 3-11) ( $R^2=36.0\%$ ) and the mean annual below-ground biomass/m<sup>2</sup> (Fig. 3-12) ( $R^2=36.4\%$ ). Mean annual below-ground biomass per stem ranged from 0.05 to 2.5 g with an overall mean of 0.84 g. Annual below-ground standing crop ranged from 2 to 738 g/m<sup>2</sup> with an overall mean of 250 g/m<sup>2</sup>. The mean below-ground weight per stem peaked at -35 cm depth while the mean below-ground standing crop peaked at -30 cm depth. General field observations indicate that the optimum

Fig. 3-11 Mean annual below-ground biomass per stem of *Scirpus maritimus* in relation to the mean water depth and conductivity (averaged to the end of July).

$$Y = 0.788 - 0.0196X + 0.0000034X^2 + 0.000054X^3 - 0.0470 \ln Z$$

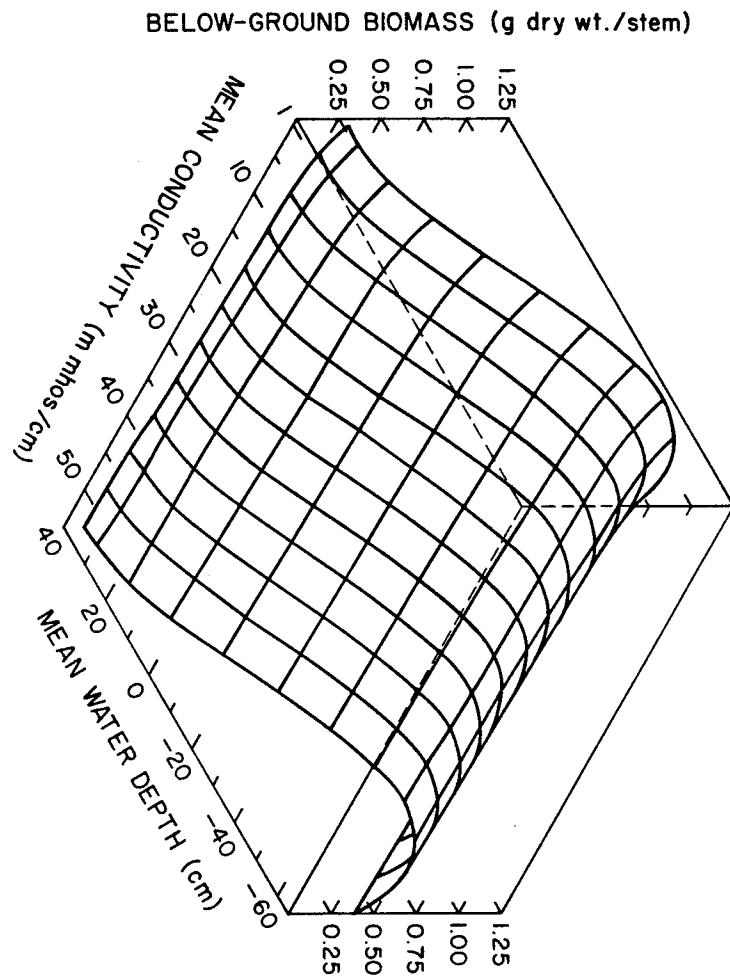
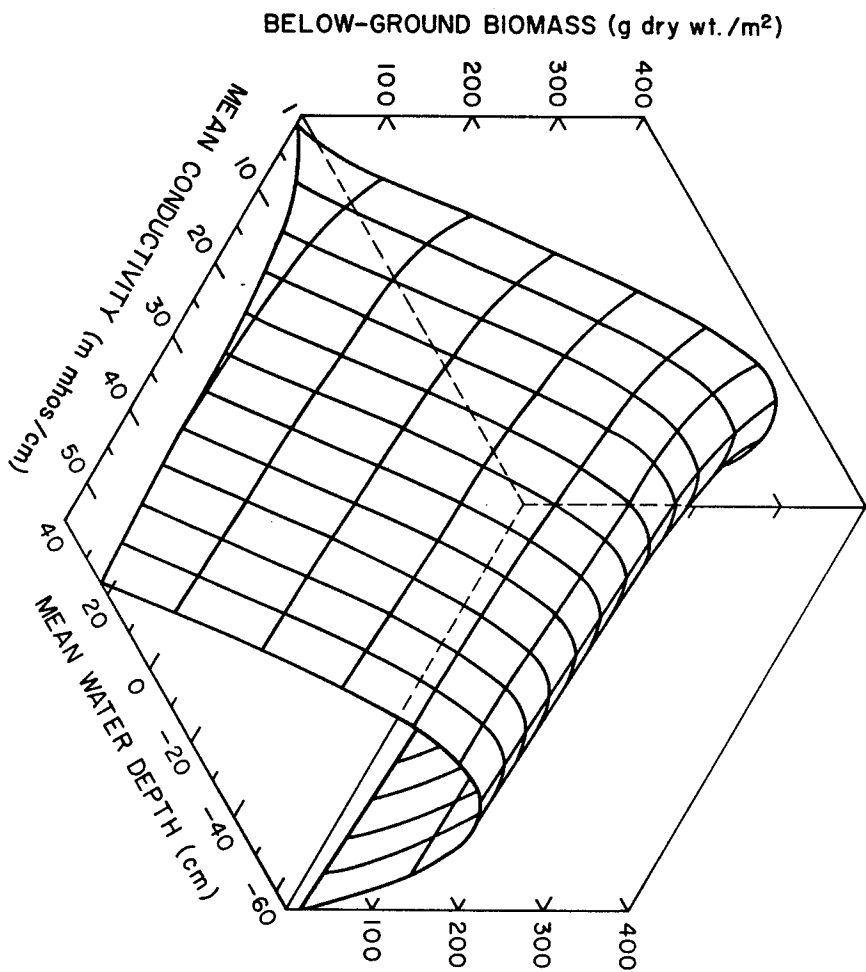
$$R^2 = .360 \quad S_y = 0.364 \quad F = 47.3$$

Fig. 3-12 Mean annual below-ground biomass of *Scirpus maritimus* in relation to the mean water depth and conductivity (averaged to the end of July).

$$Y = 254.2 - 7.170X - 0.0534X^2 + 0.00147X^3 - 18.21 \ln Z$$

$$R^2 = .364 \quad S_y = 133 \quad F = 49$$





conditions for tuber and tiller recruitment are in shallow water to mudflat conditions in mid-summer.

The same tuber can sprout viable culms in successive years. However, tubers subjected to dry conditions and high salinity ( $>50$  mmhos/cm), as in the upper slopes at sites no. 6 and 22, in 1977 and 1978, remained completely dormant. These sites were colonized by mudflat annuals and wet meadow species. In 1979, when water levels were higher the *S. maritimus* tubers produced vigorous culms. Although some tuber mortality occurred the near complete die-off of *S. maritimus* stands in dry saline conditions observed by Ungar (1968) did not occur.

Tuber death was noted in sites ice-covered over the winter, particularly in localized areas where stems had been flattened by plant debris and wave action or cut by muskrats (*Ondatra zibethica* L.)

In July and August at many of the sites which were flooded throughout the summer, roots, particularly those on the youngest tubers of the clone, developed necrotic areas and then died (e.g. Fig. 3-13). Water temperatures at this time were usually between 20 and 28°C and an H<sub>2</sub>S odour pervaded the sediments. The effect of the loss of these roots on the growth of shoots and tubers was not determined, but both shoots and tubers remained viable.

#### Seed Production

Regressions fitting the percentage of the total stems which flowered (Fig. 3-14), and the ripe inflorescence weight per fruiting culm (Fig. 3-15) had an  $R^2=36.9\%$  and  $45.5\%$ , respectively, with the mean water depth and the  $\ln$  of the mean conductivity

Fig. 3-13 Root-rot on tubers of *Scirpus maritimus*. The tuber on the right shows normal root development.

Fig. 3-14 Percent of the *Scirpus maritimus* stems which flower in relation to the mean water depth and conductivity (averaged to the end of July).

$$Y = 70.29 - 0.191X - 18.47 \ln Z$$

$$R^2 = .369 \quad S_y = 22.0 \quad F = 77$$

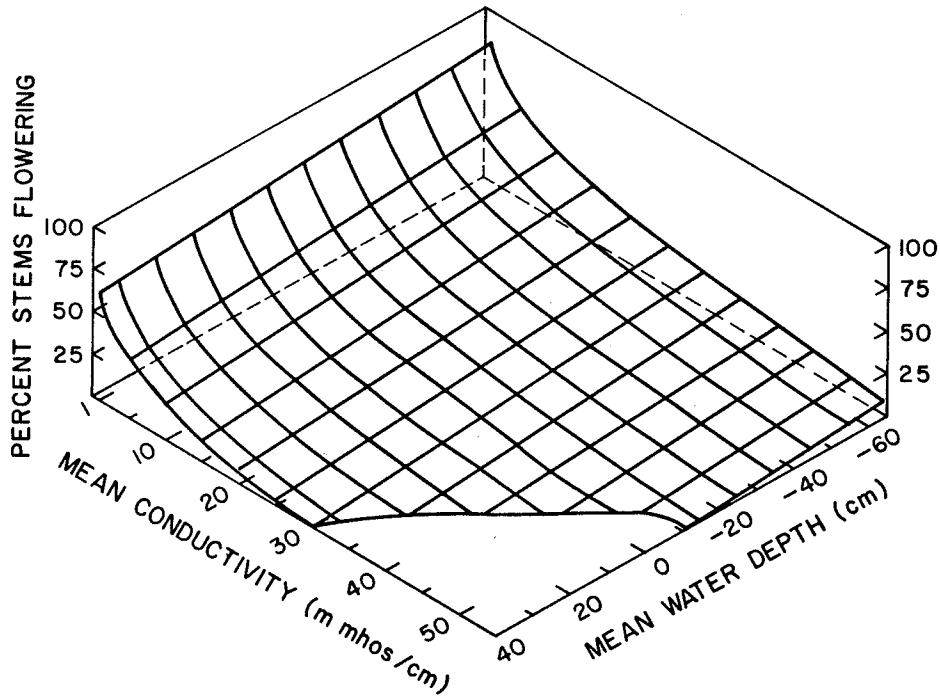


Fig. 3-15 Mean inflorescence weight per fruiting culm of *Scirpus maritimus* in relation to the mean water depth and conductivity (averaged to the end of July).

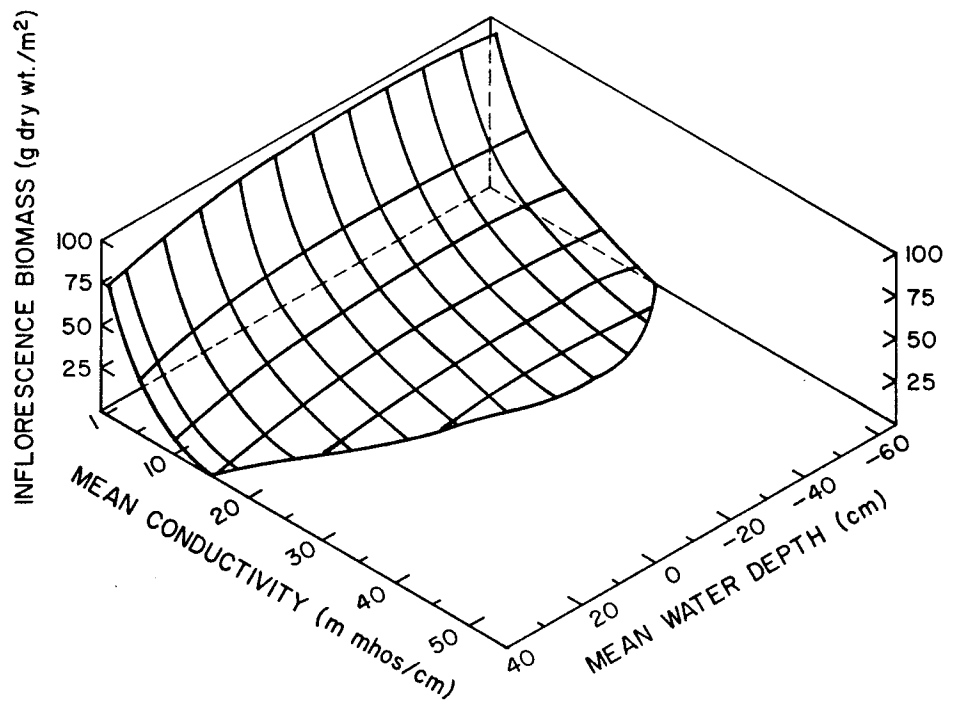
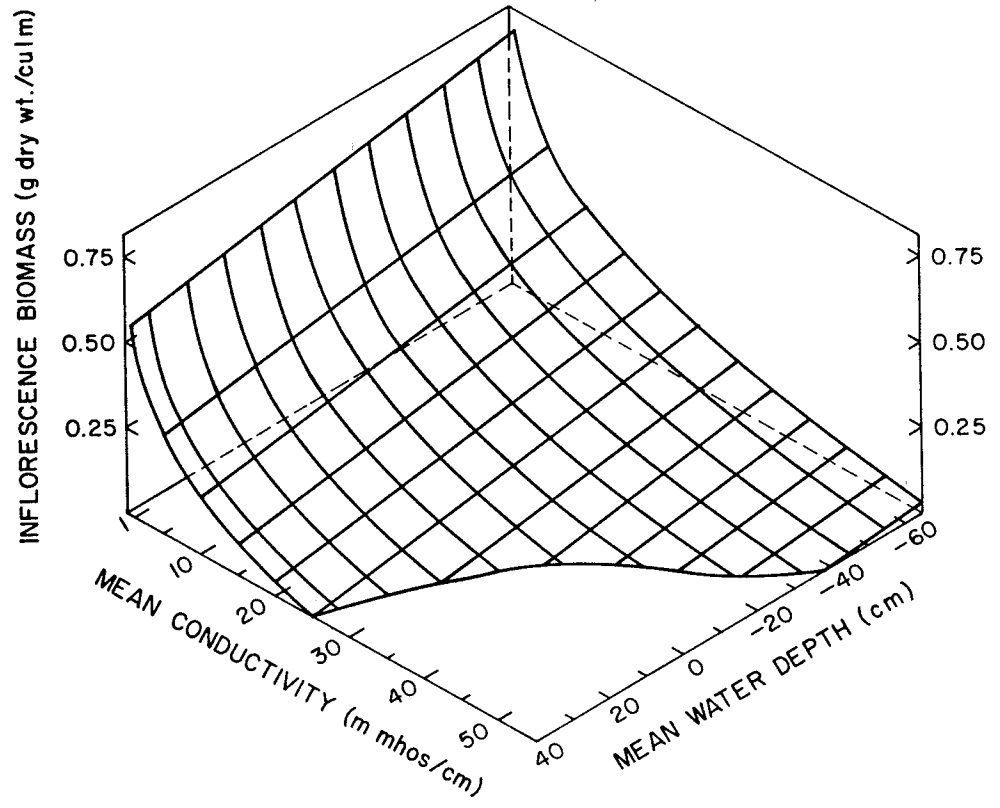
$$Y = 0.640 - 0.00171X - 18.01 \ln Z$$

$$R^2 = .455 \quad S_y = 0.162 \quad F = 93$$

Fig. 3-16 Mean inflorescence biomass of *Scirpus maritimus* in relation to the mean water depth and conductivity (averaged to the end of July).

$$Y = 94.62 - 0.255X - 0.00425X^2 - 29.63 \ln Z$$

$$R^2 = .378 \quad S_y = 31.1 \quad F = 79$$



averaged to the end of July. The stems flowering per quadrat ranged from 0 to 93 % with a mean of 34 %. Mean inflorescence weight per flowering culm ranged from 0.01 to 1.03 g with an overall mean of 0.31 g. A regression on ripe inflorescence weight/m<sup>2</sup> (Fig. 3-16) was fitted ( $R^2=36.4\%$ ) using a second degree polynomial of the mean water depth and the  $\ln$  of the mean conductivity up to the end of July. The three regressions relating to seed production showed rapid declines with increasing conductivity.

Besides water depth and conductivity influencing seed production, additional variance in the size of the inflorescences and the percentage of stems flowering can be explained by conditions during the previous summer. Sites which were dry for most of the year and flooded the following spring showed a marked increase in the number of flowering stems and in the mean weight of ripe inflorescences over the expected, considering water depth and salinity alone. Usually, only stems sprouting directly from over-wintered tubers will flower (Lieffers and Shay 1981b); however, many of the tillers flowered in sites which were dry for one growing season and then flooded the following year. Examination of the dormant buds on over-wintering tubers revealed no floral bud primordia suggesting that floral bud development occurs in the spring at the time of or after initiation of stem growth.

Sites which were continuously flooded for several years developed uniformly dense stands of *S. maritimus* on loose flocculent sediments. The percentage of stems flowering and the size of inflorescences were lower than expected when con-

sidering only the water depth and salinity; e.g. sites no.19 and 22 had uniform stands of *S. maritimus*, with a mean above-ground standing crop of over 400 g/m<sup>2</sup> but only 8% of the stems flowered.

#### Below- to Above-ground Biomass Ratio

The mean below- to above-ground biomass ratio of field quadrats ranged from 0.13 to 1.61 with a mean of 0.63. A regression fitting the mean below- to above-ground biomass ratio (Fig. 3-17) with the mean water depth and the  $\ln$  of the mean conductivity to the end of May had an  $R^2=30.5\%$ . The below- to above-ground ratio was highest at shallow depths and high salinity.

#### DISCUSSION

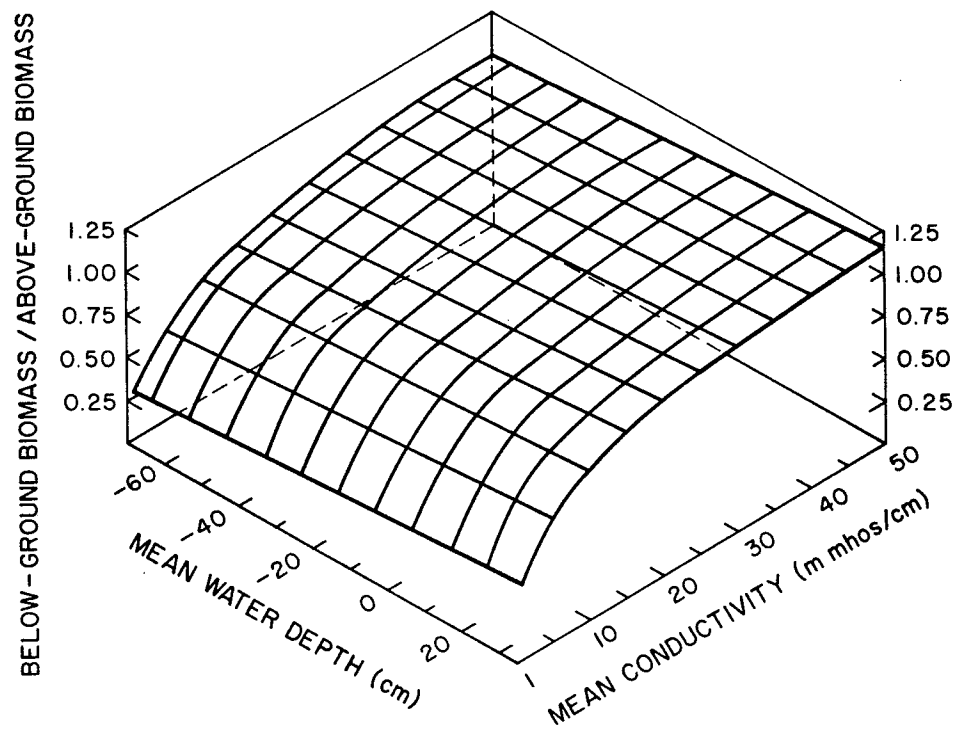
Distribution of *S. maritimus* within wetlands is related to the usual salinity class of the wetland. Langbein (1961) and Lieffers and Shay (1981d) suggest that wetland salinity at a particular water level is relatively similar from year to year. The mean water depth and conductivity at the sampling stations (Fig. 3-5) might be considered to represent the water depth salinity curve of a hypothetical section of shallow saline lake littoral zone capable of growing *S. maritimus*. It is noteworthy that in *S. maritimus* stands at water depths greater than -50 cm, conductivities were less than 8 mmhos/cm (Fig. 3-5). Unpublished data from greenhouse conditions suggests that tubers support normal growth in water -50 cm deep and at 22 mmhos/cm conductivity. Considering the shape of Figure 3-5, a portion of shallow saline lake basin with a conductivity at 22 mmhos/cm at -50 cm deep, would have a very high salinity



Fig. 3-17 Mean below- to above-ground biomass ratio of *Scirpus maritimus* in relation to the mean water depth and conductivity (averaged to the end of May).

$$Y = 0.371 + 0.0014X + 0.192 \ln Z$$

$$R^2 = .305 \quad S_y = 0.253 \quad F = 58$$



when water levels had receded to mudflat level. As *S. maritimus* seeds germinate in shallow water or wet mudflats with sediment conductivities less than approximately 20 mmhos/cm, it is likely that salinity during germination and seedling establishment controls the distribution of *S. maritimus* and probably other emergents in saline wetlands (Waisel 1972). A wetland containing a large amount of salt has successful germination and seedling establishment on the upper part of the basin slope (Fig. 3-3) where salinities of wet mudflats during drawdown and after precipitation are below a critical level. This is likely how the open alkali wetlands described by Millar (1976) develop. As water levels recede in wetlands of medium salinity (saline) a broad band of wet mudflat (Fig. 3-3) is in the salinity range appropriate for germination of *S. maritimus*. Competitor emergent species may develop higher on the basin slope where salinities are lower. In moderately saline wetlands, depending upon water levels, *S. maritimus* seedlings may establish over the entire wetland basin (Fig. 3-3). At higher water levels however, the mudflats are sufficiently fresh that other emergents establish and may out-compete *S. maritimus*. The inability of *S. maritimus* to compete with freshwater emergents was also observed by Ungar (1974). The monotypic stands in the basin centre (Fig. 3-3) are stressed and short-lived when higher water levels return.

Because of the range of water levels and salinities considered and the dominance of these two variables, multiple regression using mean water level and conductivity successfully explained a large part of the variance in *S. maritimus*

growth. The shape of the regressions followed three basic patterns. Stem height (Fig. 3-6), weight per stem (Fig. 3-7) and weight per fruiting culm (Fig. 3-8) showed sigmoidal increase with depth. Stem density (Fig. 3-9), above-ground standing crop (Fig. 3-10), below-ground biomass per stem (Fig. 3-11) and per meter<sup>2</sup> (Fig. 3-12) and ripe inflorescence biomass/m<sup>2</sup> (Fig. 3-16) rose to a maximum and decreased at increasing depth. Percent stem flowering (Fig. 3-14), ripe inflorescence weight per culm (Fig. 3-15) and below- to above-ground biomass ratio (Fig. 3-17) showed linear change with mean water depth. All, except for the below- to above-ground ratio, decreased logarithmically with increasing salinity.

In this study stem height reached a plateau level at 140 cm in water -65 cm deep. Dykyjova (1973) found that in Czechoslovakia *S. maritimus* could grow to a height of 160 cm in water 80 to 90 cm deep. The decrease in stem density at deeper water (Fig. 3-9) was also noted by Dykyjova (1973). Many of the shoots cannot reach the water surface and the successful ones have weak stems. The observation by Millar (1973) that *S. maritimus* disappears from deeply flooded sites, can be explained by the decrease in stem density, and below-ground biomass per stem and the increase in tuber winter mortality in deeply flooded sites. Stem height decreases with increasing salinity as was noted by Kaushik (1963).

Maximum standing crop within a single quadrat was 936 g/m<sup>2</sup> while the mean for all of the quadrats was 361 g/m<sup>2</sup>. Maximum standing crop of 750 to 900 g/m<sup>2</sup> (Dykyjova et al. 1971) and 480 g/m<sup>2</sup> (Ondok and Dykyjova 1973) were recorded in

natural stands in Czechoslovakia. In spite of the increase in the mean weight per stem, to a maximum of 3.2 g at -65 cm depth (Fig. 3-7), the peak above-ground standing crop occurred in water -35 cm deep (Fig. 3-10) probably because the stem density decreased at water depths greater than -30 cm (Fig. 3-9).

The survival of *S. maritimus* tubers through dry periods has also been recorded by Hejny (1960 in Dykyjova et al. 1971). This may give *S. maritimus* a survival advantage in being able to withstand the frequent periods of low water and subsequent high salinity and maintain the stored reserves necessary to respond quickly to improved growing conditions. After dry periods when water levels are raised, the wet meadow and annual colonizers disappear and the *S. maritimus*, sprouting from dormant tubers, rapidly regains dominance. The 18-fold increase in above-ground standing crop between the dry, saline conditions of 1978 and the higher water levels and lower salinities in 1979, at site no. 23, emphasises this.

The death of the roots on young tubers appears to be related to the  $H_2S$  formation in the sediments, as was discussed for rice roots by Vamos (1964). In waterlogged anaerobic soils, the  $H_2S$  in the zone surrounding roots is usually oxidized by  $O_2$  diffusion out of the roots. Warm temperatures cause increased rates of root respiration and consequently a reduction in  $O_2$  release (Joshi et al. 1975) which may result in an  $H_2S$  induced root-rot. The roots of the youngest tubers are most susceptible probably because of their high metabolic activity and the greater length of rhizome over which the  $O_2$  must diffuse.

Field data showed that the size of inflorescences increased at deeper water depths and decreased rapidly with increasing salinity (Fig. 3-15). In a greenhouse experiment (Lieffers and Shay 1981b) *S. maritimus* inflorescence size also was larger in deep water.

Bernard (1975) noted that flowering of *Carex lacustris* Willd. was dependent upon water levels the previous year; flooded conditions initiate floral primordia which develop the following year. In contrast, in saline wetlands which are dry and flooded the following year, *S. maritimus* has increased floral bud initiation and larger inflorescence size. This may be due to the aeration and accelerated decomposition in dry sediments. Kadlec (1962) noted increased decomposition and nutrient release and changes in the physical structure of sediments after drawdown. Also the shift in the dominant form of nitrogen from ammonia to nitrate upon aeration of the sediments (Ponnamperuma 1964) may be significant in the metabolism of *S. maritimus*. The fact that many of the tillers of *S. maritimus* flower later in the season in those sites which were dry the previous year suggests that the effect of the drawdown is maintained for some period after reflooding.

The August below- to above-ground biomass ratio varied from 0.13 to 1.65 with a mean of 0.63. The below- to above-ground ratio of *S. maritimus* grown in hydroponic culture was 1.2 at the end of the growing season (Dykyjova et al 1972). The below- to above-ground ratio was highest in shallow water and high salinity; conditions where the above-ground weight

per stem was low. Barko and Smart (1979) also noted a significant increase in the below- to above-ground ratio in *Cyperus esculentus* L. as the weight per stem decreased. If the below-ground biomass/m<sup>2</sup> (Fig. 3-12) is compared to the above-ground biomass/m<sup>2</sup> (Fig. 3-10) it is noteworthy that the decrease in the below-ground biomass with increasing conductivity is not as rapid as the decrease in above-ground biomass. The best correlation to the below- to above-ground ratio for *S. maritimus* was with the mean water depth and conductivity summed to the end of May. This suggests that the biomass allocation strategy of *S. maritimus* is determined by water levels and salinity conditions early in the growing season.

#### Summary

Phenotypically, *S. maritimus* exhibits a wide range of growth response to the different water depth and salinity conditions of saline wetlands in the Canadian prairies. On dry and highly saline littoral areas *S. maritimus* tubers may remain completely dormant or sprout very short, and in most cases, non-flowering stems. In shallow-water zones (0 to -35 cm) and reduced salinity, stems are taller and tillering, stem density, standing crop and tuber size are at a maximum. In deep water (> -50 cm) and low salinities, the size of individual stems and inflorescences reach a maximum; however, the much lower stem density results in reduced standing crop.

## CHAPTER 4

THE LIFE CYCLE AND SEASONAL GROWTH OF *Scirpus maritimus* L.  
var. *paludosus* (Nels.) Kük. IN SASKATCHEWAN.



## INTRODUCTION

*Scirpus maritimus* L. var. *paludosus* (Nels.) Kük. is a leafy, triangular-stemmed, clonal bulrush which, in the Canadian Prairies, is found almost exclusively in saline wetlands. This habitat provides changeable and often harsh salinity and water regimes (Hammer 1978; Lieffers and Shay 1981d).

The seasonal growth and life cycle of some wetland emergents in the north-temperate region of North America have been documented. Examples are *Scolochloa festucacea* (Willd.) Link (Smith 1973), *Carex rostrata* Stokes (Gorham and Somers 1973; Bernard 1976) *Carex aquatilis* Wahlenb. (Gorham and Somers 1973) and *Carex lacustris* Willd. (Bernard and Macdonald 1974; Bernard 1975). Few seasonal data, however, have been recorded for *S. maritimus*.

This study was undertaken to investigate the life cycle and seasonal growth of *S. maritimus*; determine clonal development and biomass allocations to individual shoots and underground portions; observe seed germination, seedling growth and other phenological aspects; and monitor the above-ground standing crop and develop a mathematical equation to describe this seasonal growth.

#### Study Sites

Three saline lakes (Strap, Indy and Porter), all within 100 km of Saskatoon, Saskatchewan were examined. The lakes were 91, 306, and 220 hectares respectively, yet the deepest recorded water depth was 1.0 m or less (Table 4-1). The

Table 4-1 Physical and chemical features of seasonal study sites of *Scirpus maritimus*.

| <u>Site</u> | <u>Lat. N</u> | <u>Long. W</u> | <u>Area (ha)</u> | <u>Maximum Basin Depth (cm)</u> | <u>Dominant Water Salts</u>     |
|-------------|---------------|----------------|------------------|---------------------------------|---------------------------------|
| Strap       | 51°47'        | 105°44'        | 91               | 66                              | Na <sub>2</sub> SO <sub>4</sub> |
| Indy        | 51°42'        | 106°32'        | 306              | 100                             | MgSO <sub>4</sub>               |
| Porter      | 52°11'        | 106°17'        | 220              | 60                              | Na <sub>2</sub> SO <sub>4</sub> |

dominant ions of these wetlands are  $\text{Na}^+$  or  $\text{Mg}^{++}$  and  $\text{SO}_4^-$ . Porter Lake is a closed basin with no surface outflow. Both Strap and Indy Lakes are Ducks Unlimited project areas and water levels were manipulated at some periods during the study.

## METHODS

### Field

In 1977 Strap Lake was sampled extensively while in 1978 and 1979 sampling was extended to include Strap, Indy and Porter Lakes. A relatively uniform stand of *Scirpus maritimus*, extending at least 50 m into the lake was selected at each site. Rain and water level gauges and a sediment sampling station were established in the centre of the *S. maritimus* zone. The slope of the lake shoreline was determined by measurement of the water depth if flooded or by a surveyor's level and rod if dry.

Sampling took place at approximately two week intervals from early May to the end of August. At each sampling period water level and rainfall were recorded and 10 cm diameter cores were extracted from the surface sediments. The cores were drained for 30 seconds and the top 10 cm was retained and air-dried. Water samples were collected in 1.0 L. polyethylene bottles from 15 cm below the water surface. Specific conductance was measured on an unfiltered portion of the sample using a Radiometer CDM2e conductivity meter standardized at 25°C. At each visit the mean stem height and the number of fruiting and non-fruiting stems were recorded in 15 randomly selected

quadrats, each 0.25 m<sup>2</sup>. The stems were clipped at ground level and fruiting and non-fruiting stems collected in separate paper bags. At Indy Lake in 1978, clonal growth was sampled at each visit by digging up five complete rhizome-shoot series, usually from areas where rhizomes were expanding into barren mudflats. Shoots sprouting directly from an overwintered tuber were considered to be the first shoot; subsequent shoots down the rhizome were numbered. The five intact rhizome-shoot series were carefully washed in freshwater and air-dried. At all visits notes were recorded on the above- and below-ground phenology of established clones and seedlings. Taxonomy is according to Scoggan (1978).

#### Laboratory

Air-dried sediment samples were finely ground in a mortar and pestle. The specific conductance of saturated paste extracts of the sediments (McKeague 1976) was determined with a Radiometer CDM2e conductivity meter standardized at 25°C.

Plant biomass was dried to a constant weight at 90°C. Fruiting culms, inflorescences and non-fruiting stems from the quadrats were weighed separately. The rhizome-shoot series samples were separated into first, second, third and fourth shoots and weighed. Their associated below-ground biomass (roots, tuber and rhizome extending to the tuber from the older shoot) was also weighed.

#### Seasonal Growth Equation

The seasonal above-ground standing crop data from Strap Lake in 1977, 1978 and 1979 and Indy and Porter Lakes in 1978 and 1979

were used in the development of the seasonal growth equation for *S. maritimus*. The form of the equation was from the logistic growth model used by Lee (1979):

$$B_t = \frac{K}{1 + e^{c - rt}} \quad (1)$$

where:

$B_t$  = above-ground standing crop/m<sup>2</sup> at time t

K = maximum attainable standing crop/m<sup>2</sup>

c = constant

r = maximum attainable rate of standing crop increase (g/day)

t = time in days from tuber sprouting (valid between 5 and 109 days)

Days after sprouting was used as the measure of seasonal time rather than calendar days because of the climatic differences in the spring temperatures between years.

The K value was estimated previously by the regression on *S. maritimus* peak above-ground standing crop/m<sup>2</sup> (Liefvers and Shay 1981a):

$$K = 523 - 8.61X + .0229X^2 + .00278X^3 - 109.5(\ln Y) \quad (2)$$

where

X = mean water depth (early May to the end of July) (valid between +40 and -65 cm mean depth)<sup>1</sup>

Y = mean conductivity (early May to the end of July) (valid between 1 and 55 mmhos/cm)

It was found that at dry sites growth rates were more rapid and above-ground standing crops approximated K at earlier dates than at deeply flooded sites. Equation (1) was there-

<sup>1</sup>+40 cm indicates that the sediment surface is 40 cm above the water surface; -65 that the sediment surface is 65 cm below the lake water surface.

fore modified:

$$B_t = \frac{K}{1 + e^{c - r(t + \frac{zX}{r})}} = \frac{K}{1 + e^{c - rt - zX}} \quad (3)$$

where

$z$  = coefficient

$X$  = mean water depth (early May to the end of July) (valid between +17 to -30 cm)

The parameters  $c$ ,  $r$ , and  $z$  were determined by the BMDP derivative-free, non-linear regression program (Dixon and Brown 1977).

## RESULTS

### Life Cycle and Clonal Growth

Culms sprout from buds on over-wintered tubers between early and late May, depending upon spring temperatures. Initiation of growth is usually a week to 10 days later than shoot growth of *Carex atherodes* Spreng. or *Scolochloa festucacea* in adjacent wetlands. The first culms grow very rapidly (Fig. 4-1C) and within two to three weeks a lateral rhizome extends outward from the tuber and eventually upward to form the first tiller (second shoot) and a tuber develops at its base (Fig. 4-2). The third and fourth shoots are produced between June and mid August (Fig. 4-1c) apparently in response to the availability of assimilates. Other sites with deeper water or higher salinity produced fewer tillers. Extensive clonal growth (Fig. 4-3) is produced under favourable conditions.

Flowering occurs by late June and is usually confined to the stems sprouting from an over-wintered tuber. Seed is

Fig. 4-1 Seasonal clonal growth of *Scirpus maritimus*,  
Indy Lake, Saskatchewan, 1978.

a) Mean below- to above-ground biomass ratio of  
the 1978 standing crop.

b) Mean below-ground biomass per stem within the rhizome-  
shoot series.

● first shoot, ▲ second shoot, □ third shoot, × fourth shoot.  
(se were all less than 20% of the mean)

c) Mean biomass per stem within the rhizome-shoot series.

Note: Each mean was derived from at least five observations.

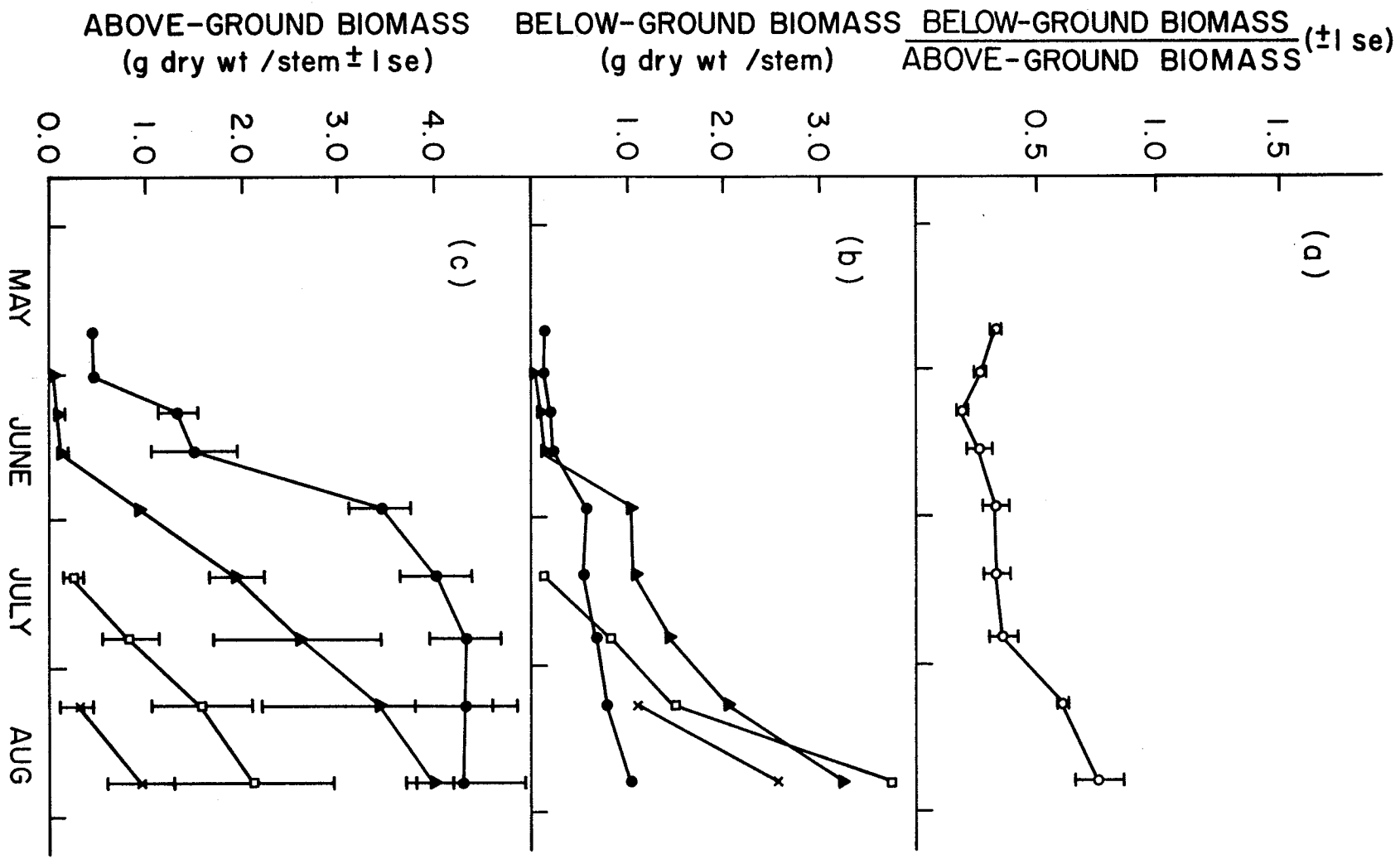




Fig. 4-2 Life cycle of *Scirpus maritimus*. Calendar depicted at the left.

Note: the source of germinating seeds is from the sediment seed bank.

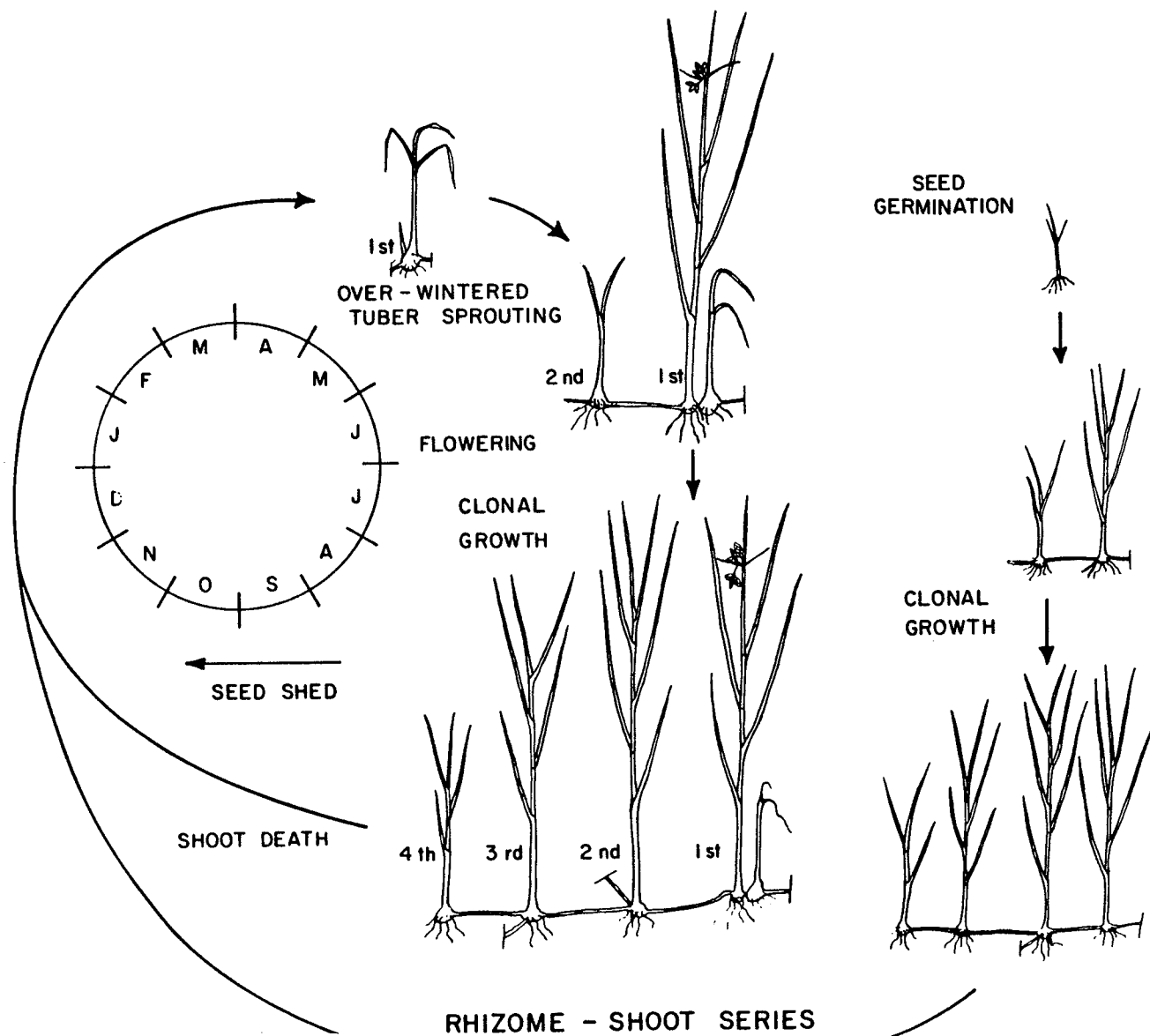


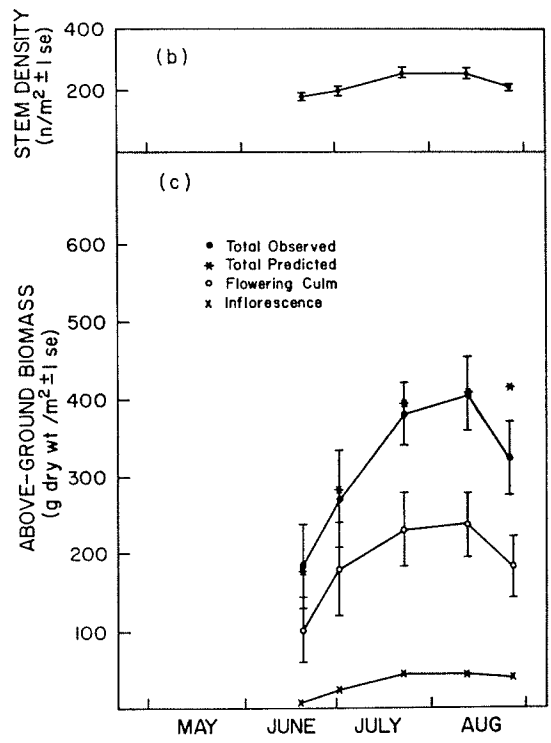
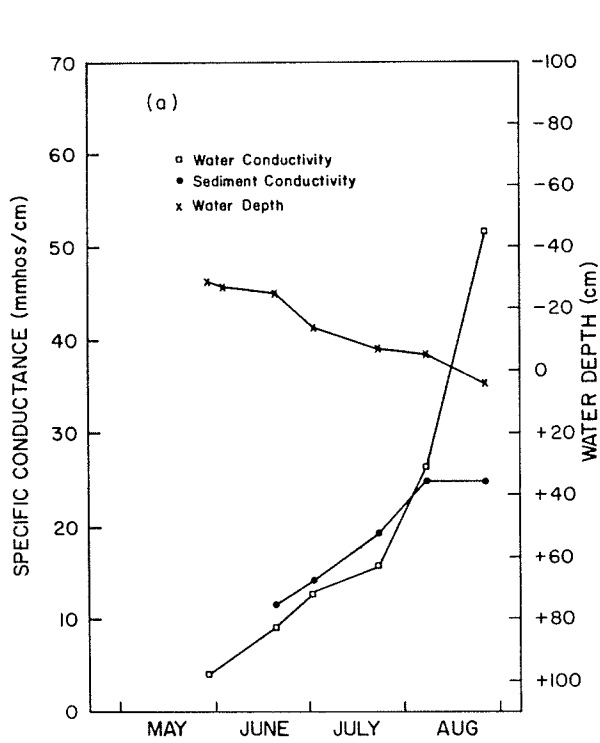
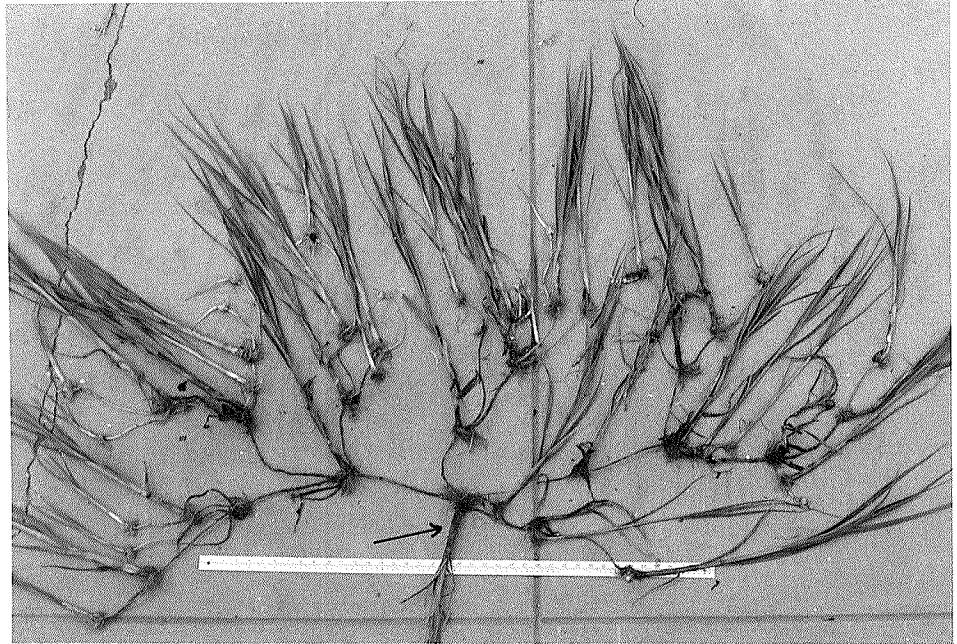
Fig. 4-3 Seasonal clonal growth of *Scirpus maritimus* at Indy Lake, Saskatchewan, August 27, 1977. The arrow indicates the first stem (bent down) produced in the 1977 growing season.

Fig. 4-4 *Scirpus maritimus* at Strap Lake, Saskatchewan, 1977.

a) Mean water depth and water and sediment conductivity (mid-stand).

b) Stem density.

c) Above-ground standing crop.



ripe by early August and, starting from the tip of the spikelets, is gradually shed throughout the fall, winter and spring of the following year.

Leaf senescence begins on the first shoots by early August or sooner, if conditions are dry and saline. Most of the above-ground biomass is killed after the first heavy frost in September and by late October all the stems are completely dead. Tubers sprout culms the following growing season and the same tuber has been observed to sprout normal culms on two successive years.

At Indy Lake, from June to the end of July, on all three years, *S. maritimus* seeds germinated and seedlings established on wet mudflats or in water less than 5 cm deep, with sediment salinities from 5 - 15 mmhos/cm. Seedling densities were up to 20/m<sup>2</sup>. Seeds also germinated within established *S. maritimus* stands but seedlings were not observed to colonize successfully.

As with established clones, after the growth of the first shoot, seedlings develop rhizomes, tillers and tubers but stem size (diameter and height) is about half that of stems from adjacent established clones. At Indy Lake approximately 1% of the seedlings produced inflorescences. Seedlings were observed to colonize barren mudflats rapidly and their overwintered tubers developed extensive stands of *S. maritimus* by the following year.

The below- to above-ground biomass ratio, of the biomass produced during the current growing season, (Fig. 4-1a) increased by late summer. Considering the sequence of individual shoots,

in late August there was a large increase in below-ground biomass and a decrease in the shoot weight from the old to the young end of the rhizome-shoot series (Figs. 4-1b and 4-1c). At this time the below- to above-ground ratio of the first, second, third and fourth shoots was 0.24, 0.82, 1.75 and 2.66 respectively. In late August tubers made up over 90% of the associated below-ground biomass for the second, third and fourth shoots.

#### Seasonal Growth at Individual Sites

Over the years examined, the three sites showed wide variation in water level and water and sediment salinity (Figs. 4- 4a, 5a, 6a, 7a, 8a, 9a, and 10a). Seasonally, the sites showed declining water levels and increasing salinity. Each spring Strap Lake was refilled by snow run-off and standing water persisted in the *S. maritimus* stand throughout most of the growing season. Only in August 1979 were water levels artificially raised (Fig.4-6a). Porter Lake was dry and very saline in 1978 (Fig.4-7a) while in 1979 it was flooded by spring run-off and had reduced salinities (Fig.4-8a). Ducks Unlimited added water to Indy Lake at the end of May and again in mid-June 1978 (Fig.4-9a). In 1979, Indy Lake was drained to facilitate construction of waterfowl nesting island (Fig.4-10a).

In early spring, as buds on over-wintering tubers developed stem density showed a rapid increase (Figs.4- 4b, 5b, 6b, 7b, 8b, 9b and 10b) and at the sites with low salinity and moderate water levels, stem density gradually increased as a result of tillering. Peak stem density was reached by late July and

Fig. 4-5 *Scirpus maritimus* at Strap Lake, Saskatchewan, 1978.

a) Mean water depth and water and sediment conductivity (mid-stand).

b) Stem density.

c) Above-ground standing crop.

Fig. 4-6 *Scirpus maritimus* at Strap Lake, Saskatchewan, 1979.

a) Mean water depth and water and sediment conductivity (mid-stand).

b) Stem density.

c) Above-ground standing crop.

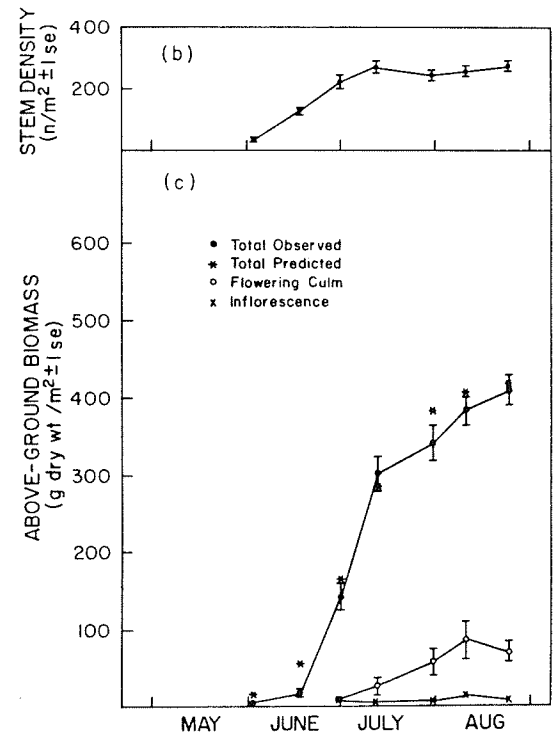
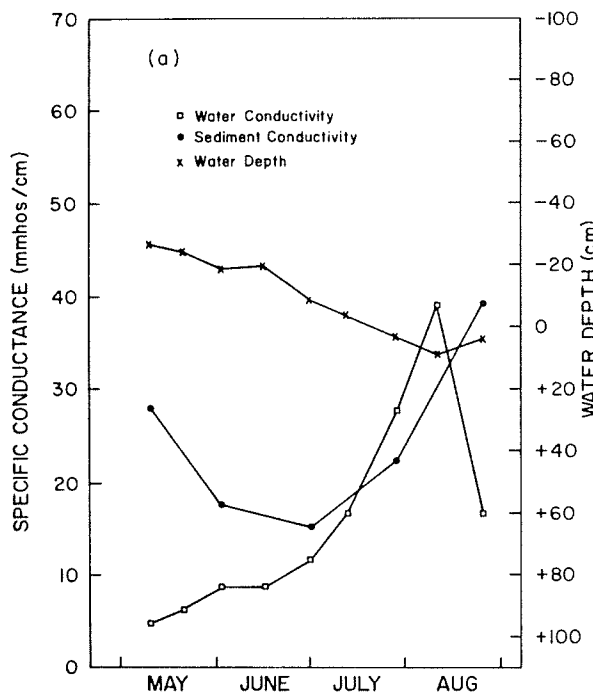
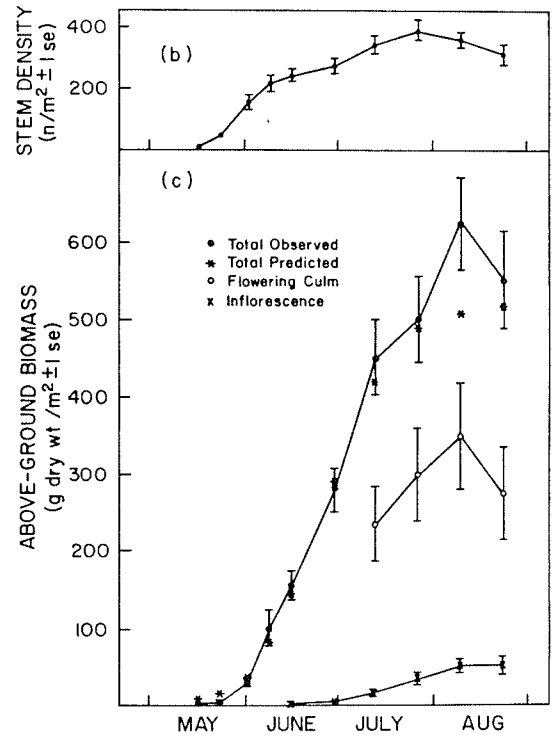
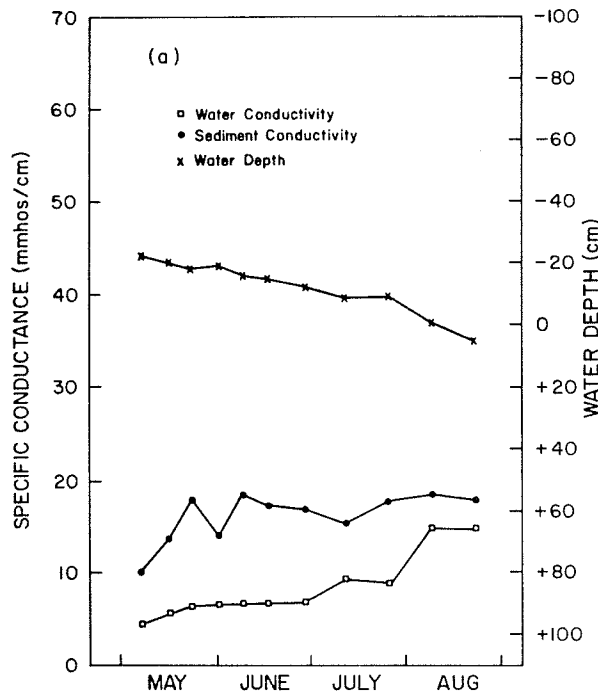




Fig. 4-7 *Scirpus maritimus* at Porter Lake, Saskatchewan, 1978.

a) Mean water depth and water and sediment conductivity (mid-stand).

b) Stem density.

c) Above-ground standing crop.

Fig. 4-8 *Scirpus maritimus* at Porter Lake, Saskatchewan, 1979.

a) Mean water depth and water and sediment conductivity (mid-stand).

b) Stem density.

c) Above-ground standing crop.

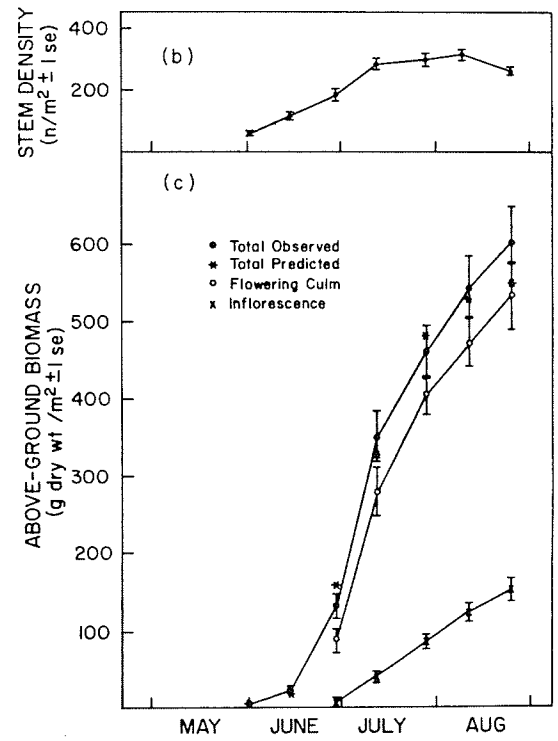
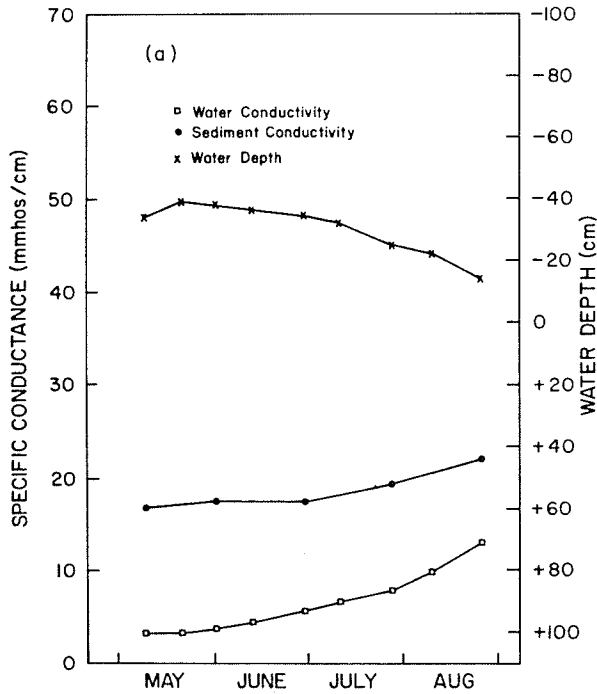
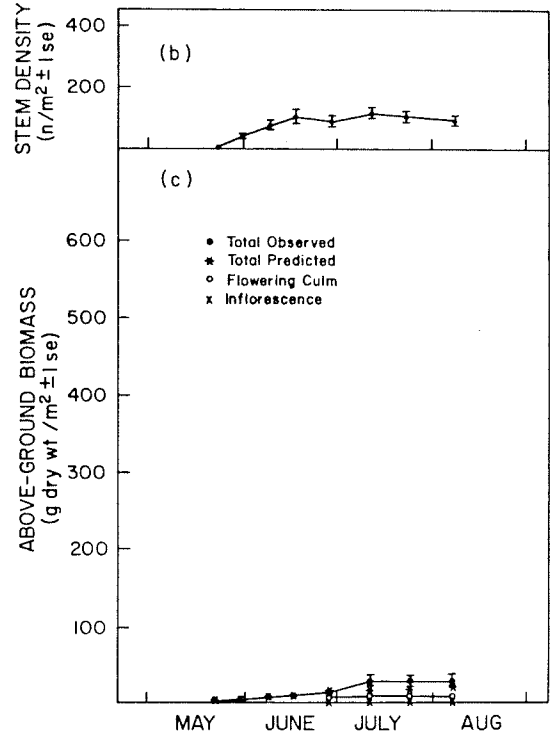
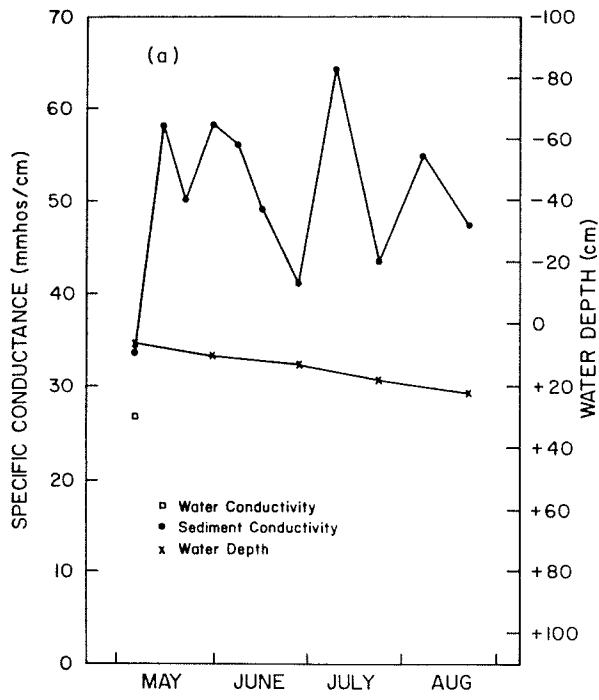


Fig. 4-9 *Scirpus maritimus* at Indy Lake, Saskatchewan, 1978.

a) Mean water depth and water and sediment conductivity (mid-stand).

b) Stem density.

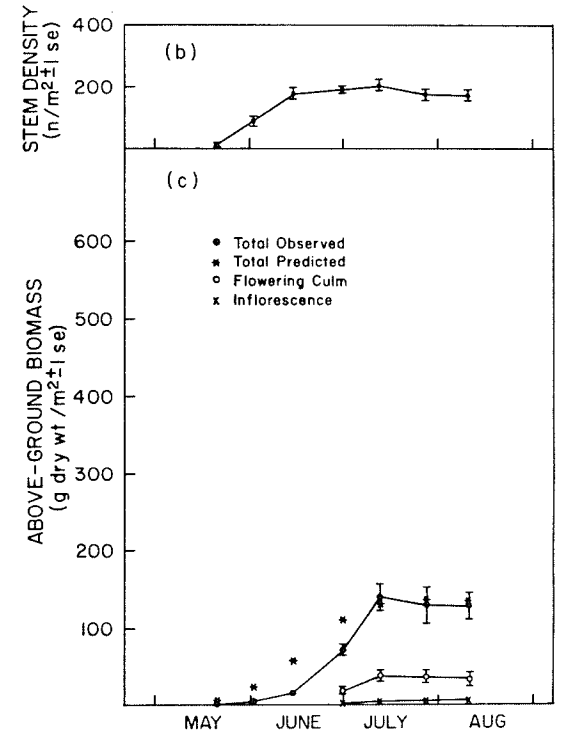
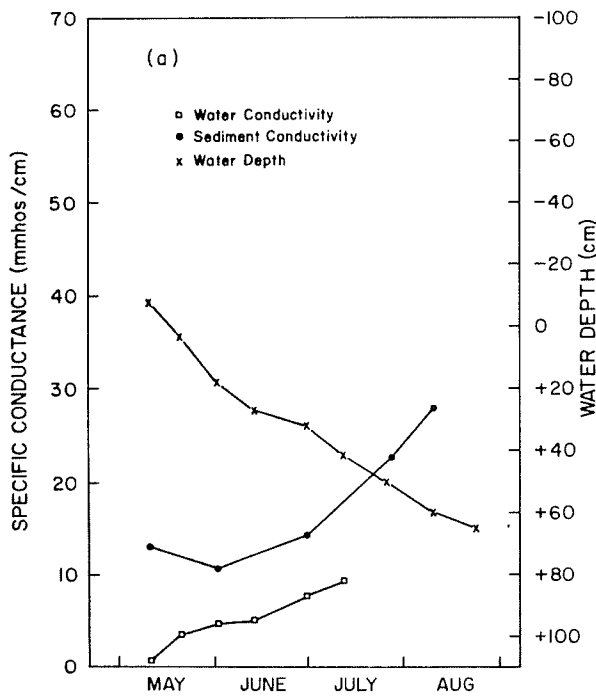
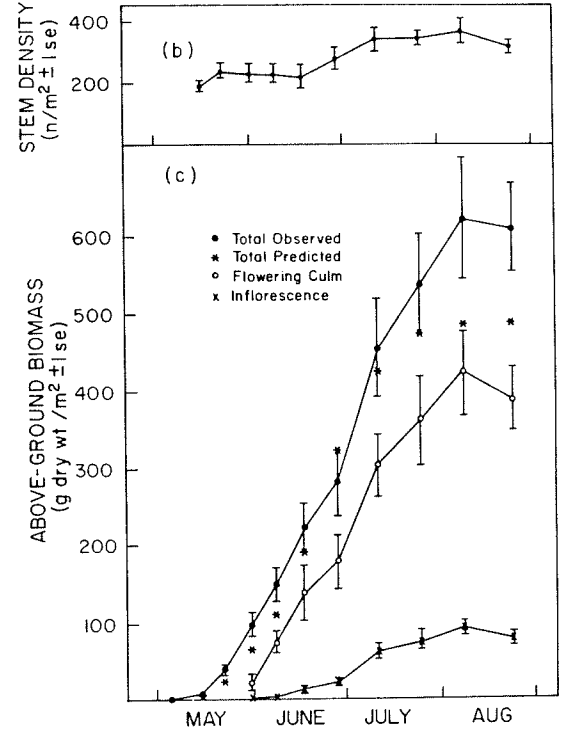
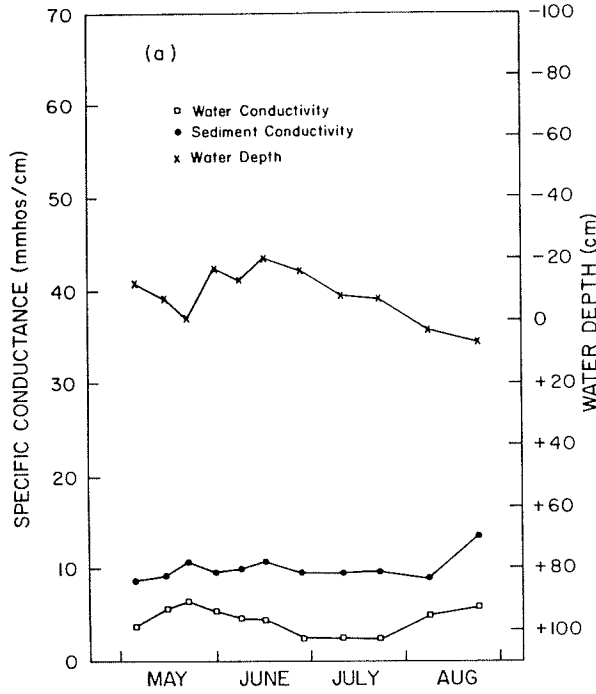
c) Above-ground standing crop.

Fig. 4-10 *Scirpus maritimus* at Indy Lake, Saskatchewan, 1979.

a) Mean water depth and water and sediment conductivity (mid-stand).

b) Stem density.

c) Above-ground standing crop.



declined later in the summer. Most of the stem mortality during the growing season was due to grazing by small mammals and in the flooded sites by waterfowl and muskrats (*Ondatra zibethica* L.). Peak stem densities exceeded 350 stems/m<sup>2</sup> at Strap Lake in 1978 (Fig.4-5b) and Indy Lake in 1978 (Fig.4-9b). Both sites had good clonal growth. Porter Lake in 1978 (Fig.4-7b) and Indy Lake in 1979 had much lower stem densities, reflecting an almost complete lack of rhizome and tiller growth.

The seasonal above-ground standing crop for Strap Lake 1977, 1978 and 1979, Porter Lake 1978 and 1979 and Indy Lake 1978 and 1979 is given in Figs.4- 4c, 5c, 6c, 7c, 8c, 9c and 10c, respectively. Associated with each is the predicted seasonal above-ground standing crop of *S. maritimus* within established stands, using the equation:

$$B_t = \frac{523 - 8.61X + .0229X^2 + .00278X^3 - 109.5 (\ln Y)}{1 + e^{3.726 - .098t - .0327X}} \quad (4)$$

The growth equation gave a good fit to the observed data ( $R^2 = 96.5\%$ ) among the different sites and years and the variable water level and salinity regimes recorded during the study.

Peak, mean above-ground standing crop weights of 625 g/m<sup>2</sup> were observed at Strap and Indy Lakes in 1978. At Porter Lake there was a 22-fold increase in the mean above-ground standing crop, from 27 g/m<sup>2</sup> in 1978 to 600 g/m<sup>2</sup> in 1979 (Figs.4-7c and 4-8c). The shift from the dry saline conditions of 1978 to higher water levels with reduced salinity in 1979 (Figs.4-7a and 4-8a) caused rapid growth of the semi-dormant tubers. A note-

worthy feature at Porter Lake in 1978, was that less than 5% of the shoots flowered, even though most of the shoots present were sprouted directly from over-wintered tubers. In contrast, with the deeper water and reduced salinity in 1979, 74% of the shoots bore inflorescences, a result of the flowering of the first shoots and many of the second and third shoots, which normally do not flower. By late August this site produced  $153 \text{ g/m}^2$  inflorescence biomass (Fig.4-8c) of which over 75% was seed.

In contrast to Porter Lake, the relatively stable flooded conditions at Strap Lake in 1977, 1978 and 1979 resulted in a *S. maritimus* stand of uniform density in 1979 (Figs.4-6b and 4-6c). Sediments within the stand were very loose and the percent flowering stems (17%) and seed biomass ( $13 \text{ g/m}^2$ ) were low.

#### DISCUSSION

Growth of rhizomatous plants involves the duplication of genetically identical subunits (Harper 1977; Noble et al. 1979). In *S. maritimus* the shoot and tuber is the clonal subunit, however the shoot dies back completely during the fall. Shoots of *Carex lacustris* (Bernard 1976), *Typha latifolia* L. (Linde et al. 1976) or *Phragmites australis* (Cav.) Trin. and other species (Shay, unpublished data) are produced in late summer, remain small and green during the winter, and undergo rapid growth the following spring. Individual shoots of *Carex rostrata* (Gorham and Somers 1973; Bernard 1976) and *C. aquatilis* (Gorham and Somers 1973) are biennial, living from 18 to 24 months. It is not unusual for plants with clonal growth (i.e. *S. maritimus*) to

have tubers that live for at least two to three years; rhizome segments of *Carex arenaria* L. may live up to seven years, even though shoots are biennial (Noble et al. 1979). Some of the factors causing *S. maritimus* tuber death are discussed by Lieffers and Shay (1981a), however more work is needed to determine the demography of tuber populations.

An increase in the below- to above-ground ratio of the clone, at the end of the growing season (Fig.4-1a), also documented for *S. maritimus* and other emergents by Dykyjova et al. (1972), is expected. As the above-ground tissue of many perennial emergents matures and senesces, organic substances are translocated to underground storage (Shay, unpublished data); in *S. maritimus* it would be to tubers which are able to undergo rapid growth the following growing season. The high below- to above-ground biomass ratio of individual stems at the youngest end of the rhizome-shoot series suggests an adaptation which promotes lateral expansion. Large tuber reserves at the outer perimeter of the clone would enable rapid stem growth and further clonal exploitation of new territory the following growing season.

The 5-20 year climatic cycles of the prairie region (Millar 1973; van der Valk and Davis 1976) cause large changes in wetland water levels. In saline wetlands there are shifts in salinity corresponding with these water level changes (Langbein 1961; Lieffers and Shay 1981d). Through much of this cycle, reproduction of *S. maritimus* is by clonal growth. *Scirpus maritimus* has two adaptations for survival during extremes in the cycle. During dry and saline periods tubers can remain completely dormant for several years and grow normally when water levels

increase (Lieffers and Shay 1981a). During periods with deep water (> -60 cm) *S. maritimus* clones become weak and gradually disappear (Millar 1973; Lieffers and Shay 1981a). The massive seed production and the dormancy of *S. maritimus* seed (George 1977) enable part of the population to survive these unfavourable periods. When drawdowns occur after high water, *S. maritimus* can rapidly colonize exposed mudflats with seedlings and clonal growth. Because of the large number of seeds which germinate, most *S. maritimus* stands are probably a mosaic of numerous clones

Some of the differences in seed production between the various sites and years appear to be related to water level stability. As noted by Lieffers and Shay (1981a) flowering and seed production are greatly increased in sites which are dry one year and flooded the next (e.g. Porter Lake in 1979). Conversely sites with stable water levels have reduced flowering and seed production (e.g. Strap Lake 1979).

Seasonal growth of *S. maritimus* in established stands, the different sites and years, generally followed the same logistic growth curve. The accuracy of the seasonal growth equation is highly dependent upon the K level, determined by the regression on peak above-ground standing crop ( $R^2 = 65\%$ ) (Lieffers and Shay 1981a). As the regression was on the standing crop of individual quadrats rather than on the means for the site, a large part of the 35% unexplained variance was probably due to random variation among quadrats. The fact that the seasonal growth equation (Eq.4), using only the mean conductivity and the water depth as environmental predictors, gave a good fit ( $R^2 = 96.5\%$ ) with the observed seasonal above-



ground standing crop, indicates the dominance of these two factors in the control of the seasonal growth of *S. maritimus*. Management efforts should focus on these two parameters.

## CHAPTER 5

THREE INSECT SPECIES ASSOCIATED WITH *Scirpus*  
*maritimus* L. var. *paludosus* (Nels.) Kük. ON  
THE CANADIAN PRAIRIES.

## INTRODUCTION

In the Canadian prairies *Scirpus maritimus* L. var. *paludosus* (Nels.) Kük. usually grows in nonspecific stands and generally occupies wide areas of the shoreline of saline wetlands. Three insect species were found associated with this bulrush, particularly in the fruiting heads and tubers. Two of the insects were *Endalus* sp.<sup>1</sup> and *Sphenophorus (Calendra) aequalis* Gyllenhal (Coleoptera:Curculionidae), while the third was a *Eupteromalus* sp. (Hymenoptera:Pteromalidae), a parasite of the *Endalus*.

Few data have been published on the genus *Endalus* except for observations on the life cycle of *E. celatus* Burke (Board and Burke 1971) and the taxonomic studies by Burke (1961) and Board (1972) who noted the association of some *Endalus* species with genera of Cyperaceae. Satterthwait (1931) and Vaurie (1951) report that *Sphenophorus aequalis* feeds upon below-ground parts of *Scirpus lacustris* L. ssp. *validus* (Vahl) Koyama and *S. fluviatilis* (Torr.) Gray. Species of the genus *Eupteromalus* have been recorded as parasites upon *Musca autumnalis* De G. (Wylie 1976) and as hyperparasites of *Bathyplectes curculionis* (Thompson) (Best and Simpson 1975).

Aspects of the distribution, life cycle, and density of these insects in selected sites in the Canadian prairies and their impact upon reproduction and productivity of *S. maritimus* were considered.

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<sup>1</sup>Currently an undescribed species (D.E. Bright written comm.).

## METHODS

Distribution of the insects in selected saline wetlands in the Canadian prairies was determined in conjunction with field work on the ecology of *S. maritimus* (Lieffers and Shay 1980a). The present discussion centres on three Saskatchewan study sites; Indy ( $52^{\circ}11'N;106^{\circ}32'W$ ), Strap ( $51^{\circ}47'N;105^{\circ}44'W$ ) and Porter ( $52^{\circ}11'N;106^{\circ}17'W$ ) Lakes. In early and late July, 1978, 20 *S. maritimus* inflorescences were collected at random along a line transect perpendicular to the shoreline of each lake. In the inflorescences *Endalus* density and life cycle stage were recorded. In 1979, 10 inflorescences were collected at five sampling periods at each site. Density and life cycle stage of the *Endalus* and the *Eupteromalus* species were again noted in each inflorescence. For the early August sampling period the numbers of damaged and undamaged seeds in each inflorescence were counted. A concurrent study (Lieffers and Shay 1981c) recorded the phenology, density and productivity of *S. maritimus* at these sites in 1978 and 1979.

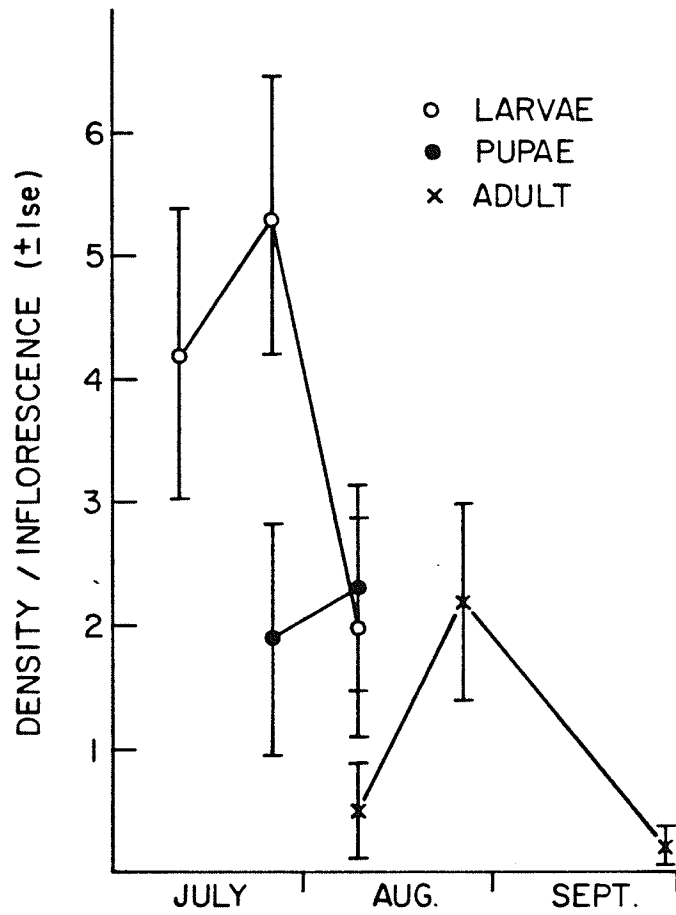
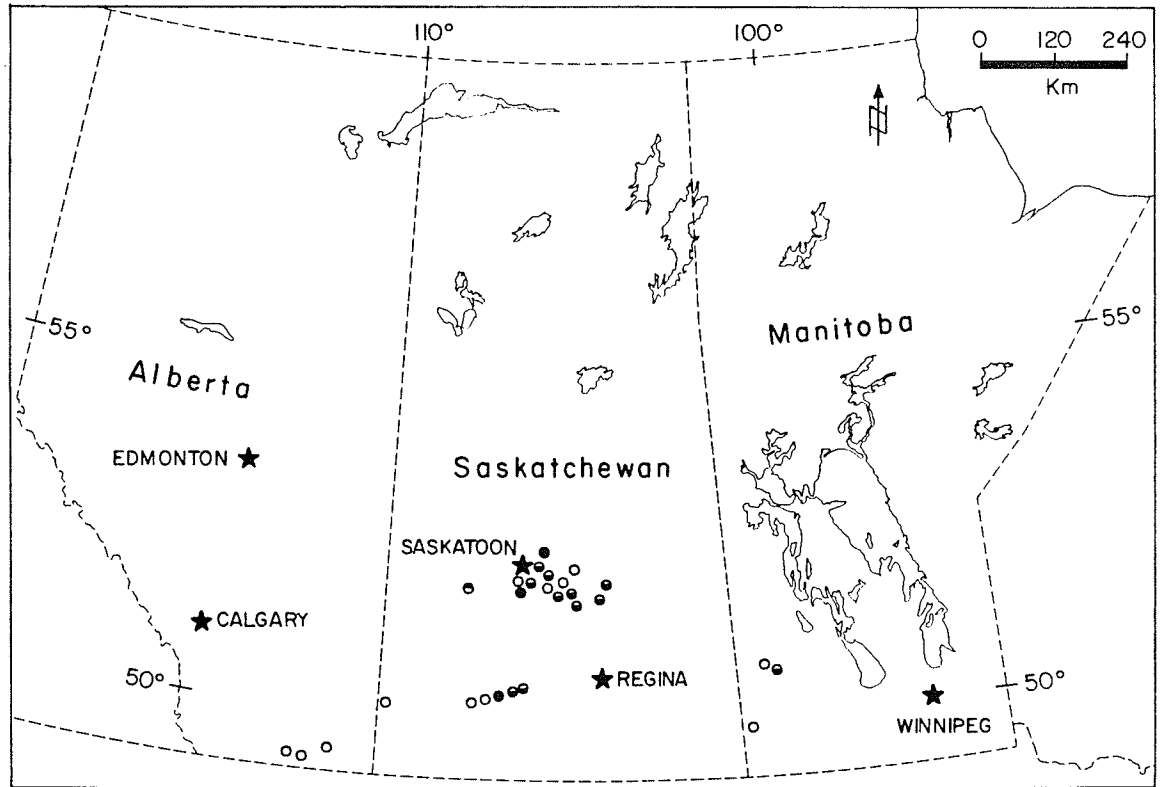
## RESULTS

The *Endalus* is widely distributed across the Canadian prairies (Fig. 5-1). It was found within inflorescences at every site examined where *S. maritimus* was dominant.

At the beginning of July *Endalus* larvae appear in the *S. maritimus* inflorescence, shortly after flowering (Fig. 5-2). The larvae burrow into, and feed upon the *S. maritimus* seeds (achenes), usually those situated in the lower, more protected parts of the spikelets. *Endalus* pupates when the seed begins to ripen,

Fig. 5-1 Collection sites of *Endalus* sp. ○ and sites also with *Eupteromalus* sp. ● and *Shenophorus aequalis* ●.

Fig. 5-2 Seasonal density and life cycle stage of *Endalus* sp. per *Scirpus maritimus* inflorescence, Strap Lake, Saskatchewan, 1979.



usually in late July. Adults emerge when seed is ripe, in mid- to late August. As the adult of the *Endalus* species can fly, the decrease in adult density in September (Fig. 5-2) is probably related to emigration from the inflorescences. No observations were made on the feeding behaviour of the adult and it is unknown how this species overwinters, however live adult *Endalus* were found on overwintered inflorescences the following spring.

The life cycle of *Endalus* appears to be related to the host plant phenology. Larvae hatch shortly after flowering (Fig. 5-2) which at most sites occurs over a two week period. There are exceptions, e.g. at Porter Lake in 1979, *S. maritimus* flowering was prolonged and occurred throughout the month of July (Lieffers and Shay 1981c). Larvae developed in both the early and late flowering inflorescences. Porter Lake therefore, reached peak *Endalus* density later in the season than the other two study sites (Fig. 5-3).

Both Porter Lake in 1978 and Indy Lake in 1979 were dry for most of the summer. The *Endalus* density per inflorescence and per square meter (Table 5-1), in these two sites and years, was much lower than at Porter Lake in 1979, Indy Lake in 1978 or Strap Lake in 1978 and 1979, which were flooded for the majority of the summer (Lieffers and Shay 1981c). At Porter Lake the density of the *Endalus* shifted from  $<6/m^2$  in 1978 to  $1164/m^2$  in 1979.

The slope of the regression line (4.02) comparing damaged *S. maritimus* seed with the number of *Endalus* per inflorescence

Fig. 5-3 Seasonal density of *Endalus* sp. (all stages) / *Scirpus maritimus* inflorescence at three sites in Saskatchewan, 1979.

Fig. 5-4 *Scirpus maritimus* seed damaged in relation to *Endalus* sp. density per inflorescence at three Saskatchewan lakes (Aug. 9, 1979).



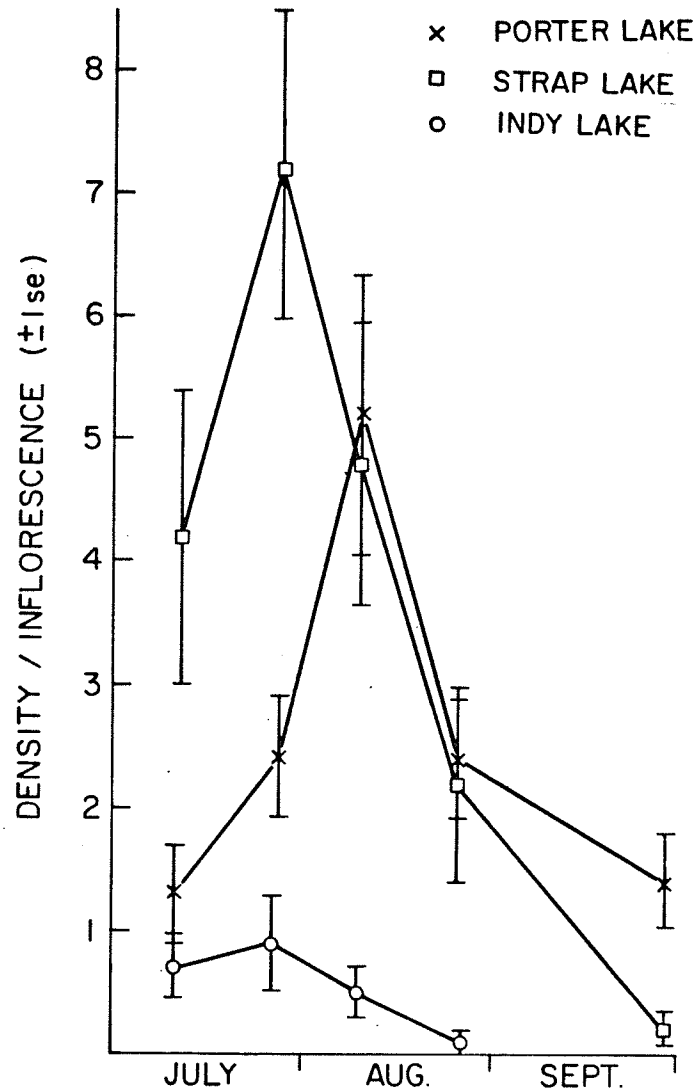
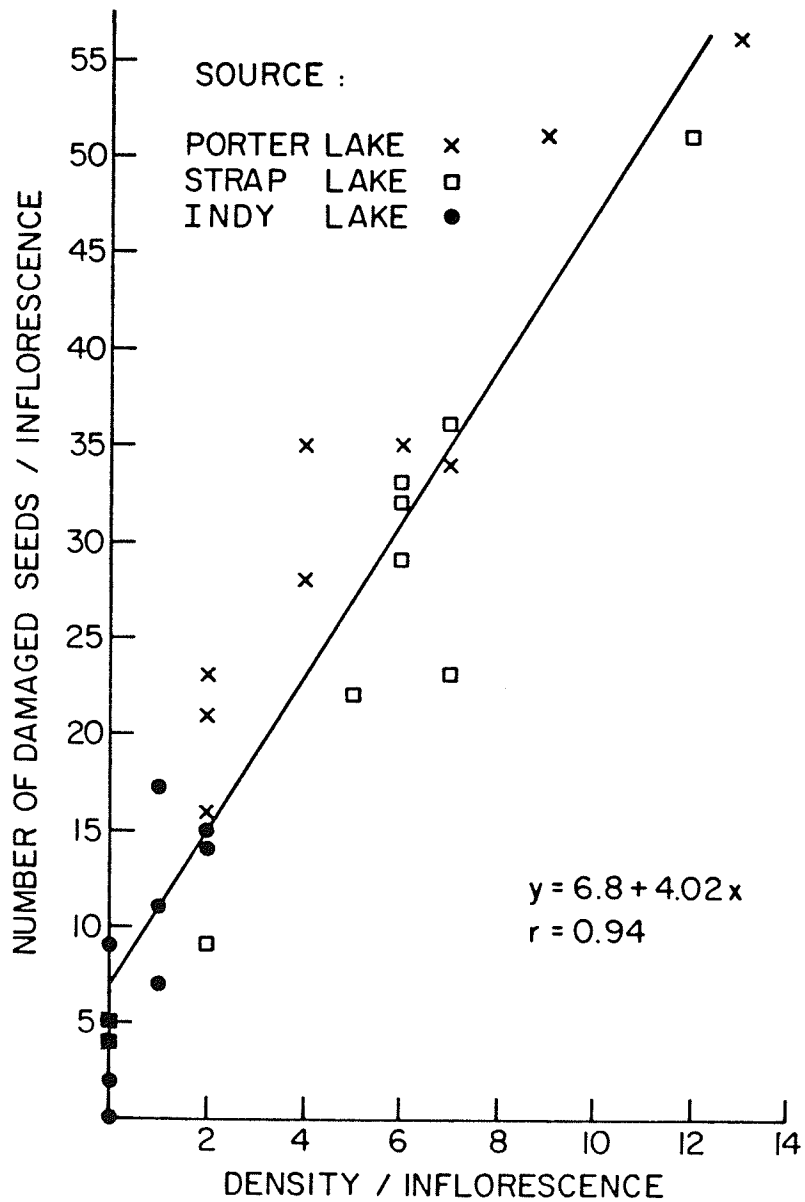


Table 5-1 Herbivory of *Endalus* sp. on *Scirpus maritimus* at three sites in Saskatchewan, 1978 and 1979 ( $\pm 1$  se).

| Site   | Year | Density <sup>a</sup> | Inflorescence <sup>b</sup> | Density <sup>c</sup> | Seed No. <sup>b</sup> | % Damaged <sup>b</sup> |
|--------|------|----------------------|----------------------------|----------------------|-----------------------|------------------------|
|        |      | Inflorescence        | (m <sup>2</sup> )          | ( m <sup>2</sup> )   | Inflorescence         | Seed                   |
| Porter | 1978 | <1.0                 | 5.9 $\pm$ 4.0              | <6                   |                       |                        |
|        | 1979 | 5.2 $\pm$ 1.1        | 224.0 $\pm$ 20.0           | 1164                 | 317 $\pm$ 37          | 11.2 $\pm$ 1.4         |
| Indy   | 1978 | 6.3 $\pm$ 1.0        | 209.2 $\pm$ 27.7           | 1318                 |                       |                        |
|        | 1979 | 0.9 $\pm$ 0.4        | 34.1 $\pm$ 8.1             | 31                   | 104 $\pm$ 11          | 8.7 $\pm$ 2.1          |
| Strap  | 1978 | 6.7 $\pm$ 0.8        | 147.7 $\pm$ 31.8           | 990                  |                       |                        |
|        | 1979 | 7.2 $\pm$ 1.3        | 43.4 $\pm$ 14.8            | 313                  | 103 $\pm$ 14          | 26.3 $\pm$ 5.6         |

<sup>a</sup> peak density of *Endalus* sp.

<sup>b</sup> early August sampling period.

<sup>c</sup> (*Endalus* sp./Inflorescence)X(Inflorescences/m<sup>2</sup>).

(Fig. 5-4) can be considered to be an estimate of the number of seeds damaged by each *Endalus* larva. At Strap Lake, August 9, 1979, a mean of 26% of the seed produced was damaged by this species (Table 5-1). Some of the smaller inflorescences had over 50% of the seed damaged.

The *Endalus* sp. was not found in the inflorescences of *Scirpus lacustris* L. ssp. *glaucus* (Sm.) Hartm. or *S. americanus* Pers., which in many sites grew adjacent to the *S. maritimus*.

After the *S. maritimus* seed was ripe and most of the *Endalus* had reached the adult stage, the *Eupteromalus* sp. larvae were found in the inflorescences, usually within the seed hollowed out by the *Endalus* larvae. By late September, 1979, mean densities were 2.8, 0.8 and 0.4 *Eupteromalus* sp./inflowescence at Strap, Porter and Indy Lakes respectively. The larvae overwinter in the standing dead inflorescences, pupate in June and emerge as adults in late June to early July.

Distribution of *Eupteromalus* sp. in the saline wetlands in the Canadian prairies is widespread (Fig. 5-1), specimens being collected from most *S. maritimus* sites examined.

The larvae, pupae and emerging adults of *Sphenophorus aequalis* were found burrowed into the below-ground tubers of *S. maritimus*. Specimens were collected from four sites in Saskatchewan (Fig. 5-1); all were in *S. maritimus* tubers on shoreline areas not flooded during the growing season. At Goose Lake, (51°46'N;107°26'W) in 1978, 13% of the *S. maritimus* tubers taken from 10 randomly selected quadrats (each 0.0625 m<sup>2</sup>) were infested by this species.

## DISCUSSION

The data suggest that the density of the *Endalus* sp. infestation per inflorescence (Fig. 5-4; Table 5-1) is similar in the sites flooded throughout most of the growing season. Because the life cycle of the *Endalus* appears to relate to the phenological stage of the *S. maritimus* inflorescences it is likely that egg laying of the adults is in response to some phenological signal from the *S. maritimus* inflorescence. Other insect species (Deseo 1976) have been observed to lay eggs near the source of specific odours. At sites which are dry (e.g. Porter Lake in 1978 or Indy Lake in 1979) these stimuli may be weakened by the low inflorescence density (Table 5-1) or reproduction and survival may be reduced by complications relating to low water levels. Indy Lake, 1978 had a mean of 6.3 *Endalus*/inflorescence and 1318/m<sup>2</sup> but the density dropped to a mean of 0.9 *Endalus*/inflorescence and 31/m<sup>2</sup> in the dry year, 1979. Theoretically there should have been ample numbers of adult *Endalus* from the 1978 season to maintain a high density per inflorescence in 1979. Since the adults can fly, many may migrate to other sites. The opposite may be true for dry, then flooded sites, such as Porter Lake where both the *S. maritimus* productivity and the *Endalus* density increased dramatically from 1978 to 1979. The increase may result from either the migration of adults into the area to lay eggs on the vigorous *S. maritimus* stands, or increased egg laying by the adults present. The 200-fold increase in population here is within the possible fecundity of most weevil species (T. Galloway pers. comm.).

The impact of *Endalus* herbivory in relation to the percent of the *S. maritimus* seeds damaged varies from site to site and is related to the inflorescence size and the *Endalus* density. Data indicate that each *Endalus* larva consumes or damages approximately four seeds (Fig. 5-4) and the *Endalus* density per inflorescence in flooded sites is relatively uniform. Those sites with small inflorescences have a higher percentage of seed destroyed. Strap Lake, 1979, (Table 5-1) had 26% of the seed destroyed by the *Endalus* while Porter Lake, 1979, with its large inflorescences, had 11% of the seed destroyed. Considering the density of inflorescences (Table 5-1), viable seed production was much higher at Porter Lake despite the larger *Endalus* population.

The *Eupteromalus* sp. is probably parasitic upon the larvae and/or pupae of the *Endalus*. *Endalus celatus* larvae are also parasitized by a pteromalid (*Trimeromicus* sp.) (Board and Burke 1971). The variability in climatic conditions and the consequent variability in *S. maritimus* growth (Lieffers and Shay 1981c) result in massive shifts in the density of the *Endalus* host species. The classic predator-prey population model of Hutchinson (1948) if applied to this system would be complicated by the variability in the growth of the host plant, which in turn is transferred to the phytophagous seed predator and its parasite.

The *Eupteromalus* sp. is an effective parasite; at Strap

Lake, 1979, densities were 2.8/inflorescence, which was 42% of the peak *Endalus* density. If each larval parasite attacks only a single *Endalus* larva, as is the case with the parasitism of *E. celatus* (Board and Burke 1971), the 42% parasitism is lower than the 60% observed by Board and Burke (1971).

## SUMMARY AND GENERAL CONCLUSIONS

An examination of saline wetlands in the Canadian prairies showed that *Scirpus maritimus* can grow in non-saline conditions but is generally restricted to saline areas because it cannot compete with other emergents in freshwater conditions. The shallow, closed, saline lakes of the prairies offer a changeable and often harsh environment. Seasonal and yearly variability in climatic conditions causes large changes in water levels and consequently salinity in these wetlands. Salinity is low when water levels are high and vice versa. The changes in salinity with water level changes are more complex than would occur when a fixed mass of solute is found in a changing volume for, depending upon water levels, salts from the sediments move into and out of the water volume. Because of this variation in salinity, an accurate and meaningful system of classification of closed wetlands must correspond to the salinity of the basin at some standard water level.

The littoral areas on which emergent plants grow undergo different patterns of salinity change at different basin positions. Under a given depth of standing water a shoreline area is less saline than a littoral area near the basin centre subject to the same amount of standing water. This feature of the basin salinity pattern, acting through the survival of seedlings on mudflats in drawdown conditions, controls the distribution of *S. maritimus* and other emergents within the basin.

The dominant aspect of the ecology of *S. maritimus* concerns its survival adaptations to the cyclic regime of the wetlands in which it grows. *Scirpus maritimus* shows wide phenotypic variation over the range of possible water depths and salinities in prairie wetlands. Generally, it grows best (peak standing crop  $>600 \text{ g/m}^2$  and density of  $300 \text{ stems/m}^2$ ) at moderate depths and salinities ( $<10 \text{ mmhos/cm}$ ) and is adapted to survive most other water depths and salinities resulting from the climatic cycles of the prairies. During dry periods and high salinity, *S. maritimus* growth is greatly reduced and in some cases tubers may remain dormant for several years but grow normally when water levels increase. During periods when water levels are high ( $> 60\text{cm}$ ) *S. maritimus* clones produce large stems but show a reduction in stem density and below-ground biomass and the entire clone may eventually die completely. The relative size of inflorescences and seed production/stem increases. As water levels recede, *S. maritimus* seedlings can rapidly colonize exposed mudflats and by clonal expansion reestablish healthy stands.

Two phytophagous insects, *Endalus* sp. and *sphenophorus aequalis*, respectively, consume seeds and tubers of *S. maritimus*. The *Endalus* as well as its parasite *Eupteromalus* sp. are widely distributed in the Canadian prairies.

In many saline wetlands management would generally entail maintaining lake water levels so that the *S. maritimus* stand is flooded for most of the growing season. To maintain vigorous growth, especially seed production, after a number



of years the lake levels should be lowered so that *S. maritimus* stands are without standing water throughout the growing season.

Salinity reduction in wetlands of higher salinity can theoretically be achieved by several means. Flushing may reduce the total mass of salts within the wetland as salt-laden water is removed. Dilution, by increasing the lake water levels and volume above the normal levels may result in some decrease in salinity. Drying and reflooding, to take advantage of the time lag for salts to move out of sediments and into the water volume, may provide a period of low salinity sufficiently long to produce healthy emergent growth.

Further research should consider aspects of saline lake hydrology as in Chapter 1, especially ground-water flow patterns and how they affect the salt budget of saline lakes. A second consideration, critical to *S. maritimus* ecology, is to elucidate the mechanisms by which drawdown conditions increase *S. maritimus* production.

An understanding of salinity patterns in closed wetlands and the responses of *S. maritimus* to specific water level and salinity regimes can provide the basis for understanding saline wetlands in the Canadian prairies and assist in their management.

## APPENDIX I

Problems in classification and management of saline  
wetlands in the Canadian prairies.

## INTRODUCTION

Effective management of the large number of saline wetlands on the Canadian prairies must be preceded by reliable assessment of the wetlands' salinities. The current classification schemes for natural wetlands in the prairie region (Stewart and Kantrud 1971; Millar 1976; Cowardin et al. 1979) put somewhat arbitrary divisions on the salinity continuum; the various classification schemes are reviewed in Millar (1976) (Table 5). They are all essentially modelled after marine and estuarine classification systems such as the Symposium of Vienna for the Classification of Brackish Waters (1959).

Problems with the existing classification systems arise when one considers the large seasonal and yearly variability in water level and consequently in salinity, which occurs in these shallow, closed inland basins. Bayly and Williams (1966), White and Hartland-Rowe (1969), Blinn (1971), Kollman and Wali (1976), Hammer (1978) and Liefvers and Shay (1981d) have all documented cases of water salinity change over a short period. Liefvers and Shay (1981a) noted that a small Saskatchewan wetland subject to large water level fluctuations, had a change in water conductivity from 54 to 1.8 mmhos/cm (hypersaline to fresh according to Millar (1976)) during a two year period. In an attempt to accommodate this variability within their classification system Stewart and Kantrud (1971) developed the widely overlapping "extreme range" categories and suggested taking an average of a multiple number of water salinity readings when determining wetland salinity.

Alternatively, both Stewart and Kantrud (1971) and Millar (1976) consider vegetation associations to be in many cases a better method of typing wetland salinity than actual salinity measurements. The problem with this concept is that the same variability in water level and salinity (particularly between years) which makes direct measurement of salinity questionable for use in classification, also affects the vegetation associations. Ungar (1974) considered that the plant communities in saline areas undergo cyclic invasion and retrogression patterns in response to pulses in water level and salinity. After a time lag they are subject to nearly as much variation as salinity measurements.

This appendix considers the problems inherent in the existing classification schemes for prairie saline wetlands and suggests some management strategies for ameliorating saline conditions.

#### SALINITY OF CLOSED WETLANDS

As much of the variation in both water and sediment salinity within closed wetland basins is related to changes in water level and lake volume, these and other physical aspects of these wetlands require careful examination.

#### Water Volume

Barica (1977) noted that under winter ice the salinity of a moderately saline wetland changed according to the equation;

$$\frac{C_x}{C_0} = \frac{V_0}{V_x} \quad (1)$$

at times 0 and x.

C = salt concentration, V = lake volume.

Water volume is inversely related to salinity. Critical to this relationship is that the mass of salts within the water remains constant. Using this model it would be easy to estimate the salinity at different water volumes.

It is generally true that as the lake volume decreases the water salinity increases and vice versa, however, the validity in all closed wetlands of the concentration-lake volume model (Barica 1977) in quantitative terms is questionable because the mass of salts within the water volume is not always constant. Langbein (1961), Driver and Peden (1977) and Lieffers and Shay (1981d) have shown that the mass of salts within some shallow saline wetlands fluctuates, particularly during water level changes. There is some evidence however, (Langbein 1961; Lieffers and Shay 1981d) that the change in mass of dissolved salts within the water follows a regular pattern in relation to lake volume and after a sufficient time delay the salinity of a wetland at a particular water level is uniform from one period to another. If this is true the salinity pattern of a wetland can be charted by following it through a complete water level cycle.

#### Littoral Areas

At any one time, the water salinity is reasonably uniform throughout a saline wetland (Swenson and Colby 1955), barring significant inflow of water from localized springs. The salinity regime of a shoreline littoral area with emergent vegetation is affected by, but different from, the water salinity of the lake (Lieffers and Shay 1981d). The difference is particularly large when littoral areas become dry and

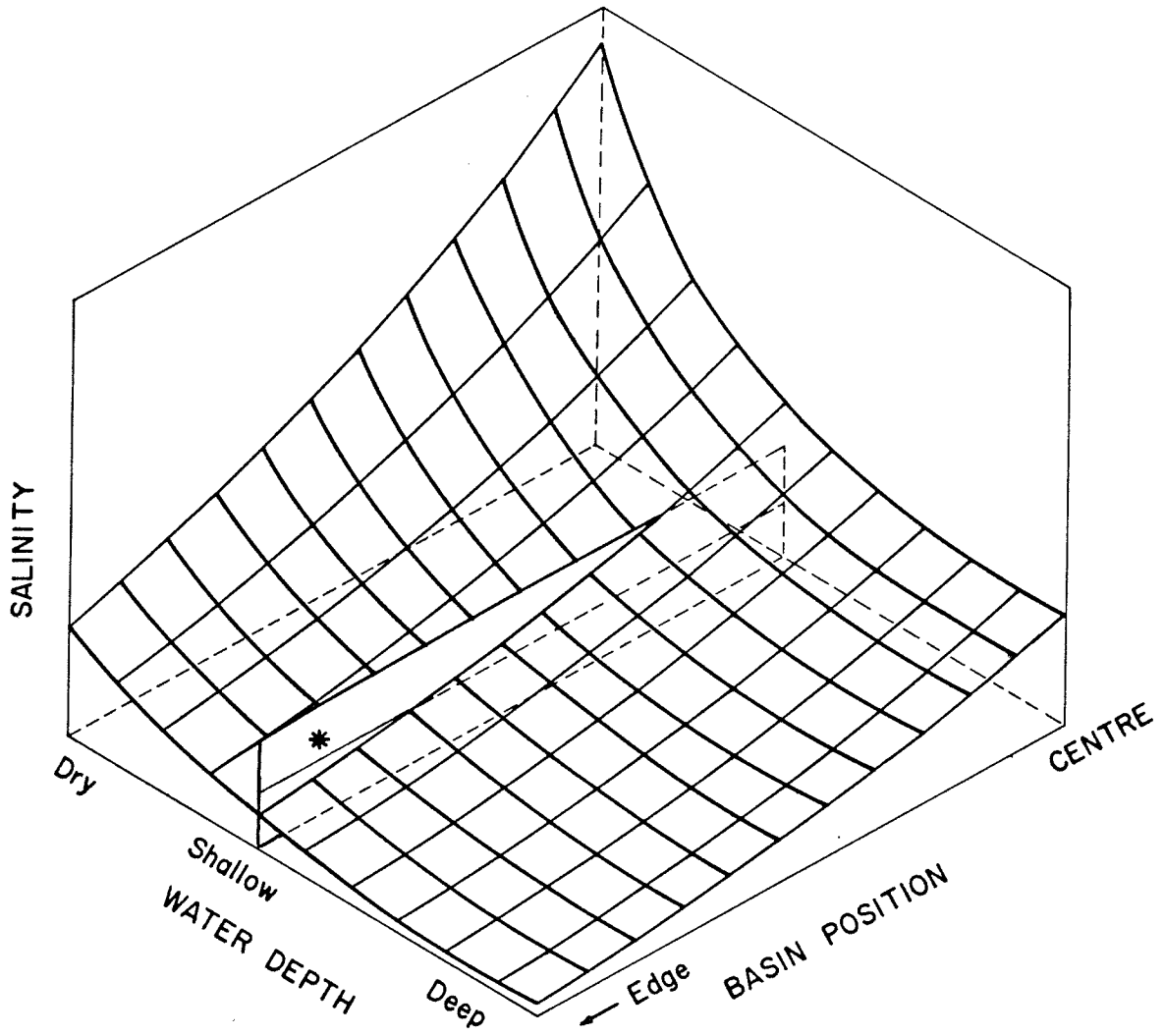
sediment salinities show a marked increase. Also littoral areas high on the basin slope are usually subject to a less saline regime than those near the deepest part of the basin (Lieffers and Shay 1981d).

Based upon the evidence of Lieffers and Shay (1981d) every littoral elevation outward from the deepest part of the basin of a shallow saline lake has a theoretical standing-water-depth-salinity curve which is relatively repeatable from one period to another (Fig. 6-1). Salt precipitation and differences in basin morphology may affect the shape of the curves and differences in the mass of salts within the (Fig. 6-1) to a higher or lower position. The basic concept however, remains, that littoral positions near the deepest part of the basin, when subject to a given amount of standing water, have a more saline regime than littoral areas high on the basin slope subject to the same amount of standing water. Lake water levels are the major factor governing the salinity of each basin elevation in a particular year.

In terms of plant growth the salinity of the zone of their occurrence is more significant than that of the water in general. Plants are tied to the salinity and water depth regime specific for each littoral zone. Theoretically, depending upon water levels, the same wetland could support various emergent species associations. Most emergent species establish in shallow water or mudflat conditions with salinities

Fig. 6-1 Standing-water-depth-salinity curves at various basin positions of a hypothetical, shallow, closed saline lake.

\* indicates the water depth and salinity range over which *Scirpus maritimus* can establish seedlings. The lower half indicates the salinity range over which most other emergents can establish.





below a critical level (assume *S. maritimus* can establish under conditions twice as saline as most other emergents). At littoral positions high on the basin slope, the standing-water-depth-salinity curves, in high water years, would intersect the mudflat depth at a salinity sufficiently low that seeds of *S. maritimus* and other emergents e.g. *Eleocharis palustris* (L.) R. & S., *Scirpus lacustris* L. and *Typha latifolia* L. could germinate and become established (Fig. 6-1). At the mid-slope of the wetland only the salt tolerant *S. maritimus* would establish. In low water years, when the deepest part of the basin becomes a mudflat, no emergents can establish because the standing-water-depth-salinity curve at mudflat levels is too saline for germination and seedling growth.

#### SALINITY CLASSIFICATION RECOMMENDATIONS

There are many academic and practical considerations in wetland classification but, from the point of view of a wetland manager a classification system, based upon salinity, should be able to type wetlands in relation to each other, thereby providing an estimate of the expected salinity and consequent plant performance. Problems arise with water level changes and the corresponding salinity variation (salinity continuum) within the wetlands. To accommodate this salinity continuum within the wetlands, a functional classification system must consider the wetland salinity at a standard water level; perhaps the normal full supply level under the natural water range, or the projected full supply level under management. This can be achieved by taking salinity readings after a

sufficient time delay, at the full supply level. If these water levels did not occur during the period of study, an estimate of the salinity at the full supply level could be made using Barica's (1977) model (Equation 1). To minimize error, the salinity and volume values from the water levels closest to the projected full supply level should be used in the calculations. Once the standard salinity of the wetland is estimated, it can be positioned on the salinity continuum between wetlands and one of the existing salinity classification schemes (Stewart and Kantrud 1971; Millar 1976; Cowardin et al 1979) applied.

#### SALINITY CONTROL OPTIONS

##### Flushing

Flushing has been used as an effective means of reducing salinity by Ducks Unlimited and other wetland managers. Rollins (1973) caused some reduction in surface sediment salinity by flooding with fresh water, allowing the salts to move into the water, and after a period of time, draining the wetland. Flushing if economically feasible in terms of both access to fresh water and a system enabling removal of the saline water, should be effective in reducing total salts, in the short-term. The permanence of the salinity reduction is probably variable from site to site depending upon groundwater quality and inflow. Langbein (1961) noted that many saline wetlands are underlain by salt deposits. Loeffers and Shay (1981d) also observed that upon reflooding a dry saline basin with fresh water,

there was a massive increase in the dissolved solids within the water but the salinity of deep sediments remained relatively constant. From the present evidence it is difficult to predict how many flushings would be necessary to produce a significant permanent salt reduction within a wetland. Under conditions of massive inflow of salinized groundwater a permanent reduction may not be feasible.

### Dilution

Fresh water could be added to the wetland to dilute the salts. This might be effective in wetlands where the basin morphology is such that after a water level increase, there are sufficient shallow littoral areas for wide bands of emergent growth. Considering Figure 6-1 if water levels were raised an emergent band of vegetation would establish on a less saline elevation higher on the basin slope. If water levels were increased sufficiently, freshwater emergents (e.g. *S. lacustris*, *T. latifolia*) could establish. Porter Lake, Saskatchewan under the water regime of the 1970s was dominated by *S. maritimus*. During the high water years of the 1950s however, *T. latifolia* and *S. lacustris* were known to flourish (landowner Pers. comm.).

There is a predictable short-term salinity reduction following the addition of fresh water. In Devils Lake, North Dakota (Swenson and Colby 1955) and in Porter Lake, Saskatchewan (Lieffers and Shay 1981d), the addition of fresh water caused a reduction in water salinity, despite the accompanying increase in the mass of dissolved salts in the water. In wetlands with a large mass of salts within the sediments

(Langbein 1961) the continued movement of salts into the water volume could negate any longterm benefits of dilution.

#### Drying and Dilution

In some lakes the basin morphology is such that it is not feasible to raise water levels because of the reduction in shallow littoral areas on which emergents grow. Also, a large mass of salts within the sediments or groundwater inflow, causing continuous increase in the mass of salts within the water, could prevent effective longterm dilution. These wetlands might still be managed in the short-term by taking advantage of the time lag in salt movements. If allowed to dry out many of the salts are forced out of the wetland, presumably into the deep sediments or to the groundwater (Liefvers and Shay 1981d). When the wetland is reflooded, initially the water salinity is low because the mass of salts within the water is reduced. At Porter Lake, 1979 (Liefvers and Shay 1981d) the mass of salts within the water gradually increased throughout the summer. The delay in the salinity increase however was sufficient to allow excellent growth of *S. maritimus* (Liefvers and Shay 1981c). These wetlands would have to be dried out in late summer and autumn or the following growing season, to force salts out of the system again, and reflooded for growth at a later date.

## APPENDIX II

The relationship between specific conductance and total dissolved solids of water from saline wetlands in Manitoba and Saskatchewan.

Specific conductance is a generalized measure of salinity widely used in limnology. It is based upon the relationship:

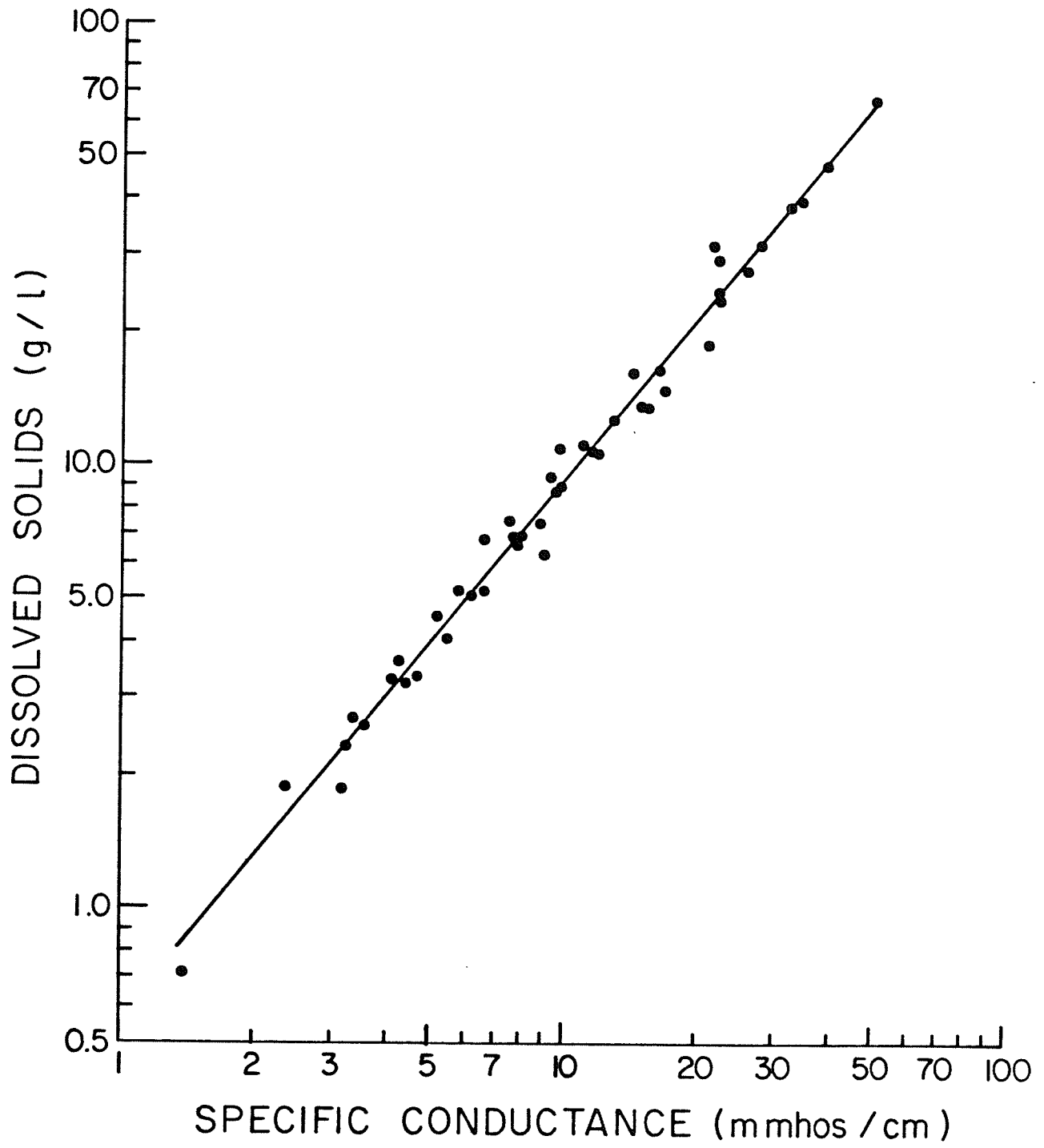
$$T = Kc \quad \text{or} \quad K = T/c$$

where; K = conductivity, c = coefficient, T = total dissolved solids.

The coefficient c depends upon the ionic composition, the level of salinity and the temperature (Williams 1966). As most lakes in the Canadian prairies are dominated by  $\text{Na}^+$  or  $\text{Mg}^{++} \text{SO}_4^-$  (Hammer 1978) the relationship between conductivity and total dissolved solids is different from those areas dominated by NaCl. Water samples from 25 wetlands in Saskatchewan and Manitoba were collected in the summer of 1979. The specific conductance was measured on unfiltered water samples using a Radiometer CDM2e conductivity meter standardized at 25°C. Samples were filtered with Whatman No. 1 qualitative filter paper and 100 ml portions were evaporated to dryness at 105°C and weighed (Rawson 1951). The relationship between specific conductance and total dissolved solids for the shallow saline wetlands examined was linear using a log log transformation (Fig. 6-2). Over the range of samples examined the relationship was:

$$Y = 2.75 + 1.21X \quad r = .992$$

Fig. 6-2 Salinity and specific conductance of water from  
25 saline lakes in Saskatchewan and Manitoba,  
1979.



## APPENDIX III

Conditions for germination of *Scirpus maritimus* L. var. *paludosus* (Nels.) Kük.

## INTRODUCTION

In natural sites, *Scirpus maritimus* L. var. *paludosus* (Nels.) Kük. seed germination provides a mechanism for rapid establishment of clones on barren mudflats. Immediately following a year of massive seed production however, only a small amount of this *S. maritimus* seed germinates. Most of the seed remains dormant. Ungar (1978) notes that halophyte seeds are able to remain dormant during unfavourable periods of high salinity and germinate when salinities decrease.

Attempts to germinate *S. maritimus* seeds under laboratory conditions or for waterfowl habitat management have had mixed results. Kaushik (1963) had germination rates of up to 70% for *S. maritimus* seeds incubated in distilled water, with decreasing germination at higher salinities. O'Neill (1972), working in California, was able to germinate *S. maritimus* seeds by treating them with sodium hypochlorite. George (1977) had variable germination rates from seed collected from several North American sources. Seed from Minnesota had low germination rates, even after sodium hypochlorite treatment.

Several laboratory experiments were conducted to determine the mechanisms that might induce germination of *S. maritimus* seed from the Canadian prairies.



## METHODS

Experiment 1

*Scirpus maritimus* seeds were collected from standing dead stems in May 1977 at Porter Lake (52°11'N;106°17'W) and in late 1977 from newly ripened stems from Strap Lake (51°47'N;105°44'W). The embryos of several randomly selected seeds were examined microscopically and it was concluded that they appeared healthy and morphologically complete. The seeds from Porter Lake were maintained at room temperature prior to germination testing. The seeds from Strap Lake were divided into several storage treatments (75 days).

|    | <u>Temperature</u>          | <u>Moisture</u> | <u>Light Regime</u> |
|----|-----------------------------|-----------------|---------------------|
| 1) | 20°C                        | dry             | normal autumn       |
| 2) | 4°C                         | dry             | darkness            |
| 3) | outdoors                    | dry             | normal autumn       |
| 4) | outdoors                    | wet             | normal autumn       |
| 5) | outdoors                    | dry             | darkness            |
| 6) | outdoors                    | wet             | darkness            |
| 7) | outdoors<br>(frozen 2 days) | wet             | darkness            |

Prior to the germination trials seeds were separated in groups and given a final treatment:

- a) no treatment.
- b) the pericarp was excised with a scalpel.
- c) leaching in distilled water on a shaker for 6 hours.
- d) 0.1% sodium hypochlorite at 45°C for 48 hours.
- e) 95% C<sub>2</sub>H<sub>5</sub>OH for 1.5 hours.
- f) 10% H<sub>2</sub>SO<sub>4</sub> for 10 minutes.
- g) 10% NaOH for 10 minutes.

Seeds were incubated on moist filter paper at 20°C, 15 hour days, 9 hour nights for 38 days.

### Experiment 2

Ripe inflorescences were collected from Strap Lake, Saskatchewan and Strathclair, Manitoba (50°25'N;100°19'W) in August 1979 and January 1980. These were kept in paper bags at 4°C until the specific storage treatment. Pericarps of all the seeds were cut with a scalpel before specific storage treatments.

|    | <u>Temperature</u> | <u>Moisture</u>    | <u>Light Regime</u>                 | <u>Time</u> |
|----|--------------------|--------------------|-------------------------------------|-------------|
| 1) | 4°C                | distilled<br>water | darkness                            | 180 days    |
| 2) | 20°C               | anaerobic mud      | darkness                            | 40 days     |
| 3) | 20°C               | distilled<br>water | normal late<br>winter and<br>summer | 180 days    |

In August 1980, seeds were incubated on moist filter paper at 20°C, 15 hour days and 9 hour nights and a second set at 32°C, 15 hour days and 9 hour nights.

### RESULTS

There was poor germination success (maximum < 6%) in all the tests tried. None of the treatments were significantly better than the others.

## DISCUSSION

The sodium hypochlorite technique (O'Neill 1972) probably is effective in breaking down the pericarp of the *S. maritimus* achene. The fact that this technique and other mechanisms which weaken the pericarp, are not effective at promoting germination in this study or with the seeds collected from Minnesota (George 1977), suggests that other dormancy mechanisms, perhaps one of the many documented by Taylorson and Hendricks (1977) is inhibiting germination.

In the field *S. maritimus* seeds germinate in large numbers however, in productive years massive quantities of seed are produced (Lieffers and Shay 1980a). A dense stand of *S. maritimus* seedlings may reflect the germination of only a small fraction of the seed produced. It is clear that the seed can remain dormant for several years prior to germination. The washing and diluting effect of rainfall on mudflats (Waisel 1972) may be a necessary requirement for germination. George (1977) had germination rates up to 18% from seed stored 11 years. Long dormancy periods could give *S. maritimus* the ability to survive the unstable environmental conditions of prairie saline lakes.

## APPENDIX IV

Water and sediment salinity data from Blondie and  
Strap Lakes, Saskatchewan, 1979.

Table 6-1 Chemical composition of Blondie Lake water for sampling periods in 1979.

| Sample Date | Field pH | Conductivity mmhos/cm | SO <sub>4</sub> <sup>=</sup> | Cl <sup>-</sup> | CO <sub>3</sub> <sup>=</sup> | HCO <sub>3</sub> <sup>-</sup><br>(mg/l) | Na <sup>+</sup> | Mg <sup>++</sup> | Ca <sup>++</sup> | K <sup>+</sup> | Na <sup>+</sup> /Mg <sup>++</sup><br>(meq/l) | SO <sub>4</sub> <sup>=</sup> /Cl <sup>-</sup><br>(meq/l) |
|-------------|----------|-----------------------|------------------------------|-----------------|------------------------------|---|-----------------|------------------|------------------|----------------|--|--|
| May 10      | 7.5      | 1.4                   | 295                          | 13              | -                            | 110                                     | 72              | 80               | 18               | 10             | .47  | 15.3   |
| May 20      | 7.7      | 2.4                   | 840                          | 37              | -                            | 215                                     | 150             | 145              | 35               | 10             | .54  | 17.5   |
| June 1      | 7.7      | 3.3                   | 1455                         | 63              | -                            | 325                                     | 290             | 245              | 70               | 30             | .62  | 16.8   |
| June 14     | 8.0      | 4.1                   | 1535                         | 67              | -                            | 430                                     | 360             | 315              | 80               | 50             | .60  | 16.8   |
| July 1      | 8.0      | 5.2                   | 2130                         | 104             | -                            | 630                                     | 480             | 405              | 125              | 70             | .62  | 15.3   |
| July 11     | 8.2      | 5.8                   | 2440                         | 115             | -                            | 630                                     | 490             | 425              | 100              | 70             | .61  | 15.8   |
| July 26     | 8.7      | 6.6                   | 3130                         | 155             | 40                           | 570                                     | 595             | 505              | 90               | 70             | .62  | 14.8   |
| Aug 10      | 8.4      | 7.5                   | 3750                         | 180             | 6                            | 700                                     | 755             | 655              | 125              | 80             | .61  | 15.6   |
| Aug 24      | 8.1      | 9.8                   | 6640                         | 220             | -                            | 895                                     | 1190            | 1070             | 185              | 80             | .58  | 22.2   |
| Sept 29     | 8.5      | 14.3                  | 8300                         | 315             | 6                            | 1280                                    | 1585            | 1440             | 250              | 170            | .58  | 19.6   |

Table 6-2 Chemical composition of Strap Lake water for sampling periods in 1979.

| Sample Date | Field pH | Conductivity mmhos/cm | SO <sub>4</sub> <sup>=</sup> | Cl <sup>-</sup> | CO <sub>3</sub> <sup>=</sup> | HCO <sub>3</sub> <sup>-</sup><br>(mg/l) | Na <sup>+</sup> | Mg <sup>++</sup> | Ca <sup>++</sup> | K <sup>+</sup> | Na <sup>+</sup> /Mg <sup>++</sup><br>(meq/l) | SO <sub>4</sub> <sup>=</sup> /Cl <sup>-</sup><br>(meq/l) |
|-------------|----------|-----------------------|------------------------------|-----------------|------------------------------|---|-----------------|------------------|------------------|----------------|--|--|
| May 9       | 7.6      | 4.6                   | 1520                         | 175             | -                            | 240                                     | 630             | 125              | 100              | 10             | 2.66   | 6.45   |
| May 20      | 7.8      | 6.2                   | 2350                         | 366             | -                            | 350                                     | 920             | 180              | 200              | 20             | 2.70   | 4.75   |
| June 2      | 7.8      | 8.0                   | 3330                         | 468             | -                            | 400                                     | 1233            | 245              | 225              | 30             | 2.65   | 5.25   |
| June 15     | 8.0      | 8.8                   | 3360                         | 509             | -                            | 480                                     | 1410            | 290              | 235              | 30             | 2.56   | 4.85   |
| June 30     | 8.0      | 11.8                  | 4820                         | 610             | -                            | 410                                     | 1860            | 380              | 240              | 50             | 2.59   | 5.83   |
| July 12     | 8.6      | 16.8                  | 6800                         | 955             | 42                           | 210                                     | 2655            | 530              | 325              | 100            | 2.65   | 5.24   |
| July 28     | 8.5      | 27.8                  | 14920                        | 2080            | 30                           | 275                                     | 5830            | 1060             | 350              | 160            | 2.89   | 5.28   |
| Aug 11      | 9.3      | 39.2                  | 24100                        | 3160            | 85                           | 300                                     | 9910            | 1670             | 350              | 220            | 3.11   | 5.62   |
| Aug 25      | 8.2      | 16.5                  | 7720                         | 1120            | -                            | 360                                     | 2790            | 595              | 325              | 80             | 2.47   | 5.18   |
| Sept 29     | 8.7      | 7.7                   | 3020                         | 520             | 35                           | 390                                     | 1190            | 270              | 170              | 40             | 2.33   | 4.30   |

Fig. 6-3 Seasonal specific conductance of Blondie Lake sediments at various basin positions and depths.

Fig. 6-4 Seasonal specific conductance of Strap Lake sediments at various basin positions and depths.

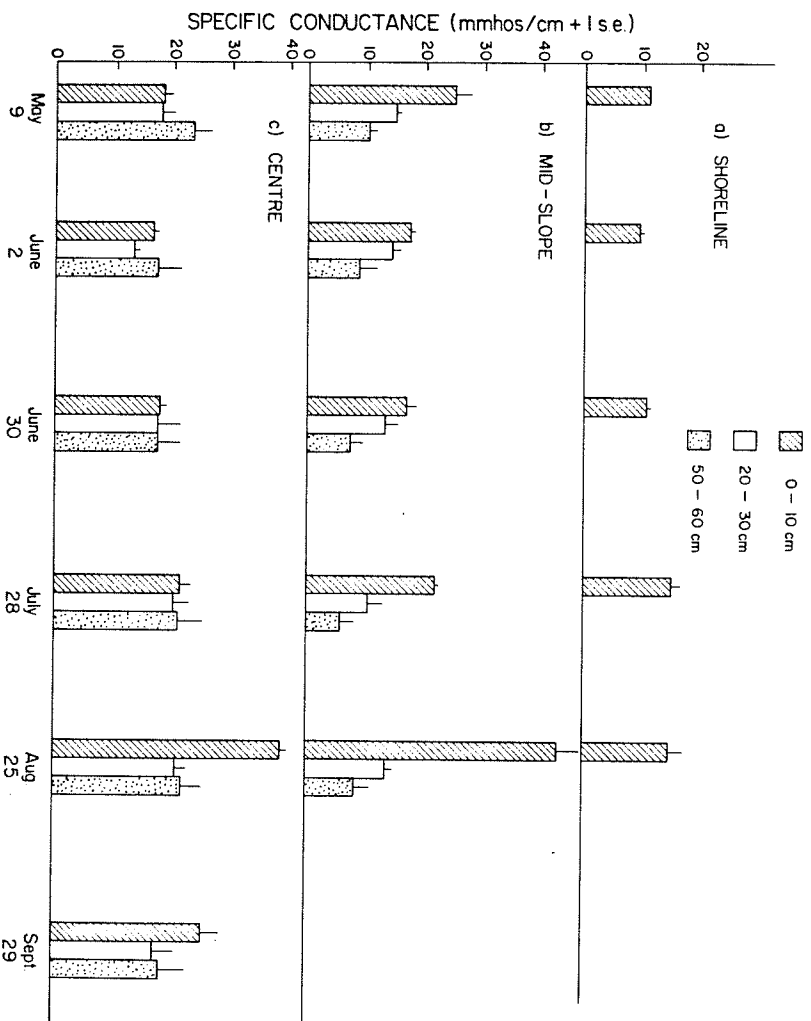
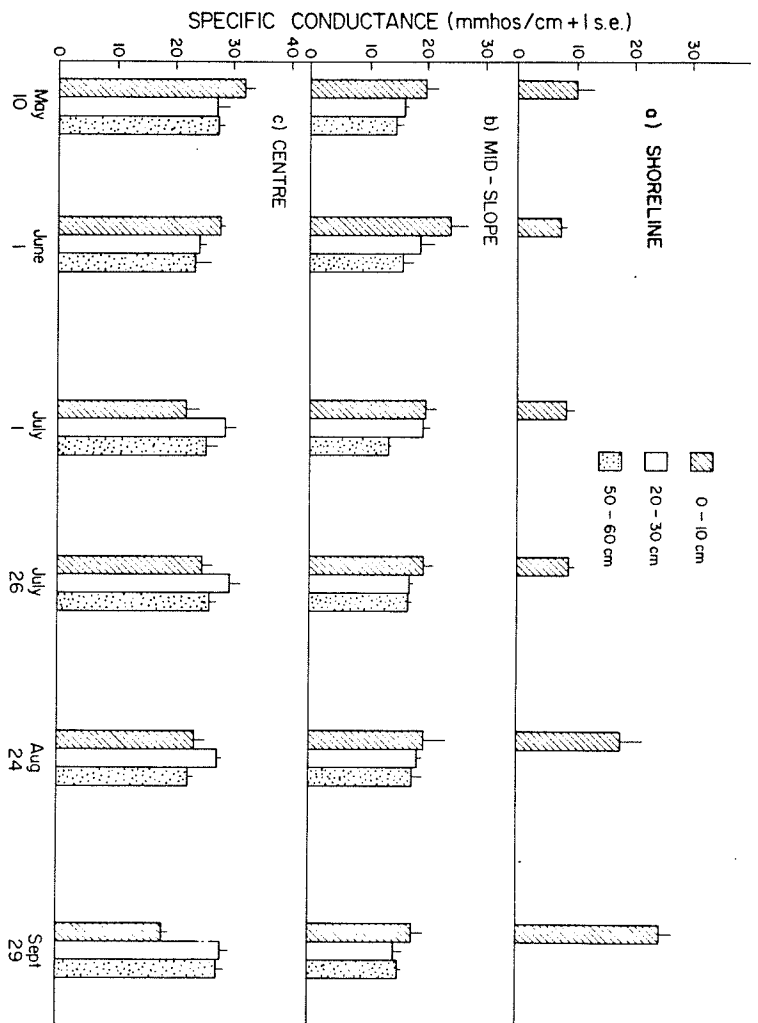




Fig. 6-5 Bathymetric map of Porter Lake, Saskatchewan.  
Contours in cm.

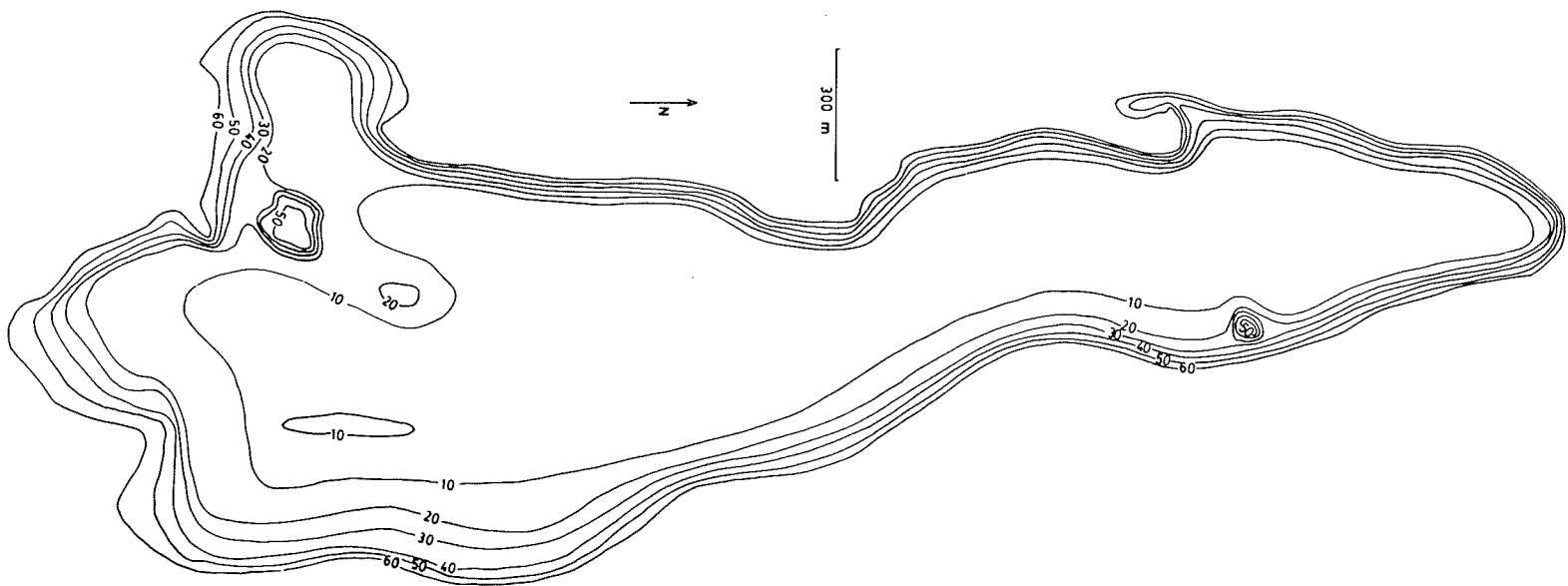


Fig. 6-6 Bathymetric map of Blondie Lake, Saskatchewan.  
Contours in cm.

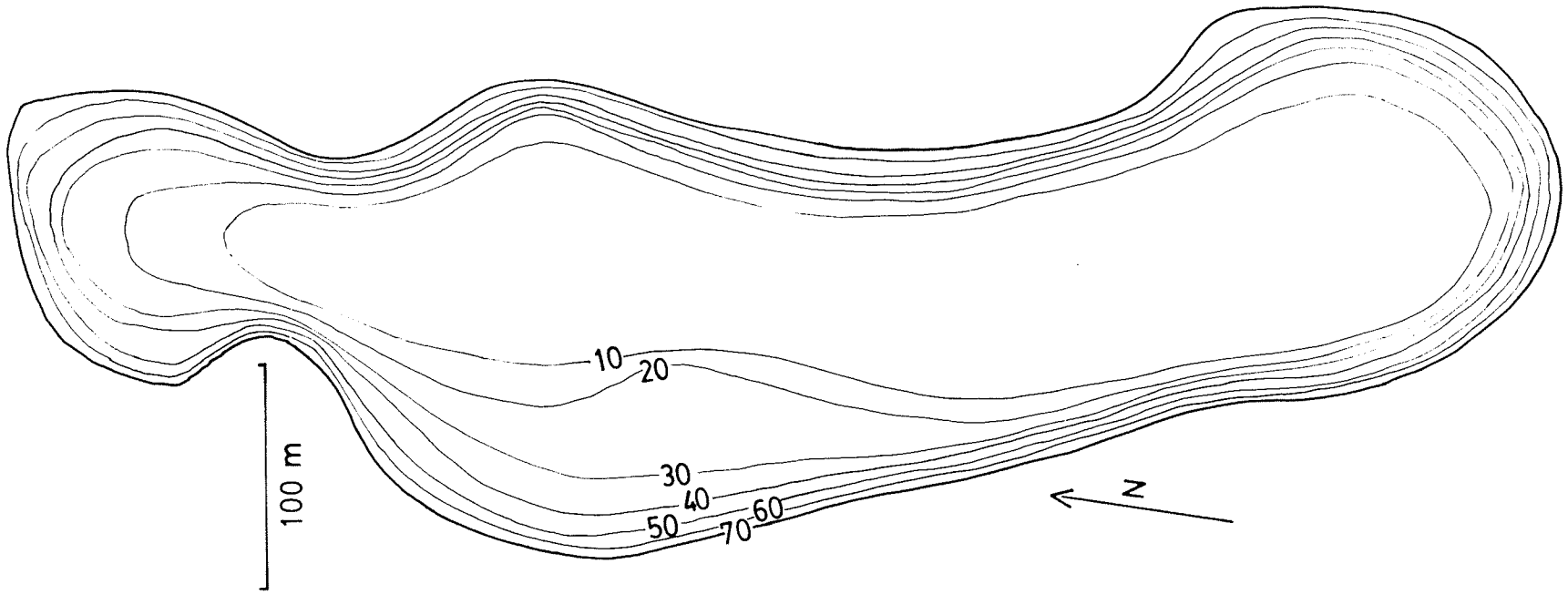
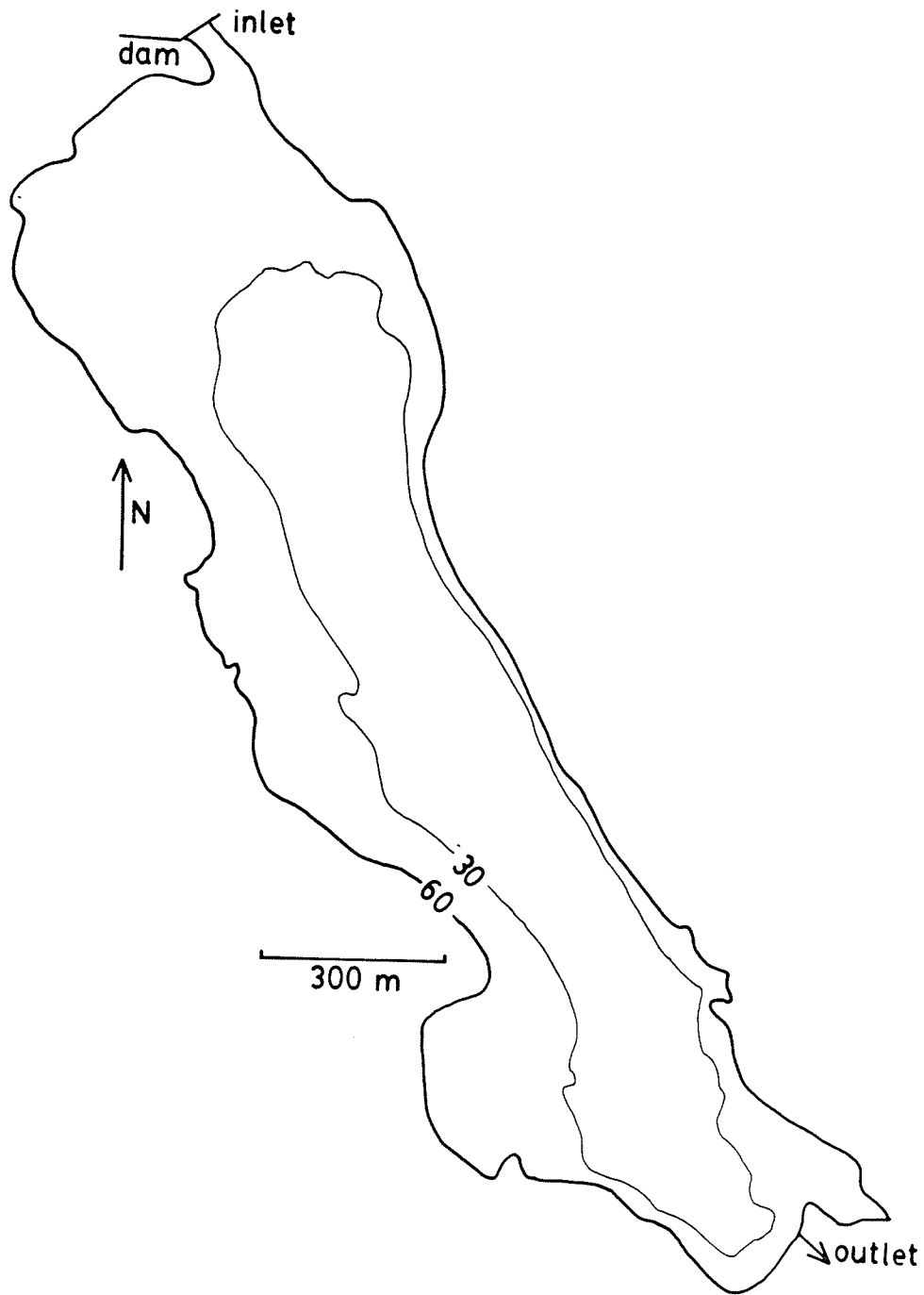


Fig. 6-7 Bathymetric map of Strap Lake, Saskatchewan.  
Contours in cm. Originally drawn by Ducks  
Unlimited (Canada).



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