Copyright is owned by the Author of the thesis. Permission is given for a copy to be downloaded by an individual for the purpose of research and private study only. The thesis may not be reproduced elsewhere without the permission of the Author.
The life history strategy of Carex pumila Thunb. (Cyperaceae), a rhizomatous perennial pioneer species on the sand plains of the dune system of coastal Manawatu

A thesis presented in partial fulfilment of the requirements for the degree of Doctor of Philosophy in Botany at Massey University

R. E. Burgess
1984
ABSTRACT

The life history strategy of *Carex pumila* Thunb. (Cyperaceae), a major colonist of raw moist sand on the sand plains of coastal Manawatu, New Zealand, is outlined. By virtue of the continuous formation of sand plains, sites suitable for colonization are a permanent feature of this habitat and vegetation of increasing seral maturity is represented at any one time across a series of adjoining deflation hollows and low dunes. It is proposed that the species is an r-strategist well suited to exposure, nutrient stress and seasonal flooding. Amelioration of these conditions by deliberate perturbation treatments resulted in this seral species responding in a way that ultimately lead to its more rapid demise.

The species has a rhizomatous perennial growth habit. The modular construction of its rhizome system is described for the first time. Similarly, the occurrence of both long and short sympodial rhizome branches and of large-diameter sinker roots have not been previously described in the literature on this species. Its floral development appears to be environmentally cued. Emergence of inflorescences occurs in early October. Maximum size of dissemules is obtained by early January. Subsequently seeds are shed and the shoots bearing them die. The species is essentially allogamous, although in a laboratory experiment, it was found to be partially self-compatible. Self-pollination must be expected in the field since neighbouring shoots are likely to be part of the same genet.

Field studies are reported in which the performance of *Carex pumila* was monitored, firstly at sites of increasing seral maturity both in space and in time, and secondly in response to perturbation treatments. Populations showed a pattern of development that included
a juvenile phase of rhizome expansion, an adolescent phase of increasing shoot density, a mature phase in which a proportion of the shoots were reproductive, and a senile phase of diminished growth and seed production. Phasic development was more protracted on the more stressed and more exposed sites. Other species more rapidly filled the space made available by the death and decay of Carex pumila shoots, than the colonist itself. As a pioneer, the species is doomed to extinction on the sites it colonizes.

In a perturbation experiment, the sward mass of the total vegetation per unit area was increased at all sites by nitrogen fertilizer, applied as ammonium ions at a rate of 50 kg N / ha. Where the Carex pumila population was in a senile phase in an old deflation hollow, the increase was made mainly by other species. In younger populations on a low dune, the density of shoots and expanding buds of Carex pumila were markedly increased by the fertilizer treatment. Associated with this, a significant increase occurred in the proportion of the total dry weight of vegetative branches in rhizomes and in green leaves.

A nitrogen limitation to seed yield was indicated at the older low dune site. Here nitrogen fertilizer addition increased seed output per unit area by increasing both seed number per culm and seed size. By contrast on the younger low dune site, seed output per unit area was unchanged by the perturbation. In this population, reallocation of resources within fertile shoots, which was seen as an increased number of seeds per culm, was offset however by a reduction in fertile shoot density.
Seed reproductive effort varied between 0 and 16% of total biomass, whereas rhizome allocation was more variable; up to 100% of biomass where the species was invading an embryonic deflation hollow. As a proportion of the biomass of fertile shoots alone, seed reproductive effort estimates of up to 32% were obtained.

The post-anthesis photosynthetic contribution of female spikes to final seed weight was estimated at 26%, in a growth room experiment. This estimate is considered conservative given that final seed weight was not significantly reduced by defoliation and shading of the culm. Thus, the allocation of biomass to seeds cannot be considered a drain on the carbon resources of the plant that might otherwise be allocated to growth or some other plant function.

Total nitrogen concentrations were dissimilar in different plant parts and, for comparable organs, between populations of different ages. Thus, allocation patterns to component parts based on dry weight and total nitrogen were different. Given that nitrogen was seen to be limiting growth in this seral habitat, the allocation of this resource is likely to be of greater significance in the evolution of life history strategies than is that of dry weight.
ACKNOWLEDGEMENTS

I record with appreciation the assistance and encouragement given to me by the many people who made the completion of this thesis possible. I especially thank Dr J Skipworth for his supervision, Mr G Arnold for statistical guidance, Dr R R Brooks and Dr R Haselmore for guidance in analytical procedures, Mr B Campbell, Ms L Rhodes, Mr K Kelliher and Mr A Tucker for technical assistance, Mr I Gray and Dr P Gregg for plant and soil analyses, and Ms J Tipoki for typing. I am indebted to Dr W A Laing who made critical comments on drafts of this thesis. I am also grateful to the N. Z. Forest Service for allowing me to undertake the field work on the Tangimoana State Forest, to Plant Physiology Division, D.S.I.R. for use of the Climate Laboratory, and to Mr and Mrs H Ellison for rainfall data and access to the field study area. I also record my appreciation to Massey University, Community Volunteers, Palmerston North (Inc) and Grasslands Division, D.S.I.R. who employed me during this period.

Finally I thank my family for their forebearance.
# ACKNOWLEDGEMENTS

# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>Life histories, allocation of resources and reproductive effort</td>
<td>2</td>
</tr>
<tr>
<td>1.2</td>
<td>Successional trends of reproductive effort</td>
<td>7</td>
</tr>
<tr>
<td>1.3</td>
<td>Quantification of life history strategies</td>
<td>13</td>
</tr>
<tr>
<td>1.4</td>
<td>Sand plains and water-logged soils</td>
<td>21</td>
</tr>
<tr>
<td>1.5</td>
<td><em>Carex pumila</em> Thunb.</td>
<td>26</td>
</tr>
<tr>
<td>1.6</td>
<td>Aims of the study</td>
<td>29</td>
</tr>
</tbody>
</table>

# CHAPTER 2 ASPECTS OF THE BIOLOGY OF *CAREX PUMILA*

<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>Growth habit</td>
<td>33</td>
</tr>
<tr>
<td>2.2</td>
<td>Germination</td>
<td>38</td>
</tr>
<tr>
<td>2.3</td>
<td>Seedling morphology</td>
<td>39</td>
</tr>
<tr>
<td>2.4</td>
<td>Shoot phenology</td>
<td>39</td>
</tr>
<tr>
<td>2.5</td>
<td>Self incompatibility</td>
<td>43</td>
</tr>
<tr>
<td>2.6</td>
<td>The contribution of reproductive assimilation to seed production</td>
<td>50</td>
</tr>
</tbody>
</table>

# CHAPTER 3 INITIAL FIELD STUDIES

<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1</td>
<td>Description of the habitat</td>
<td>63</td>
</tr>
<tr>
<td>3.1.1</td>
<td>The study area</td>
<td>63</td>
</tr>
<tr>
<td>3.1.2</td>
<td>Climate</td>
<td>65</td>
</tr>
<tr>
<td>3.1.3</td>
<td>Wind speeds</td>
<td>67</td>
</tr>
</tbody>
</table>
3.1.4 Vegetation cover ........................................ 69
3.1.5 The water table ........................................ 73
3.1.6 Soil water profile ...................................... 77
3.1.7 Soil nutrient and organic matter status .......... 79
3.1.8 Nitrogen fixation ...................................... 84

3.2 Carex pumila on the sand plains ....................... 89
  3.2.1 Phasic development .................................. 89
  3.2.2 Rates of clonal spread ............................... 95
  3.2.3 Leaf litter decomposition ........................... 102

CHAPTER 4 FIELD PERTURBATIONS
4.1 Introduction ............................................. 110
4.2 Methods and materials .................................. 116
4.3 Results and discussion ..................................
  4.3.1 Aerial shoot densities ............................... 126
  4.3.2 Leaf area ............................................. 138
  4.3.3 Age and size distributions .......................... 139
  4.3.4 Dry weight, energy, elemental contents .......... 143
  4.3.5 Flowering and seed production .................... 185
  4.3.6 Allocation of dry matter and total nitrogen ...... 199
  4.3.7 The effect of nitrogen fertilizer addition ....... 225

CHAPTER 5 DISCUSSION ..................................... 254

REFERENCES .................................................. 281
LIST OF FIGURES

2.1 The rhizome axis of Carex pumila illustrating its basic morphology.

2.2 Vertical growth of a primary rhizome axis.

2.3 Rhizome looping down into the substrate.

2.4 Short branch modules.

2.5 Basic linear pattern of rhizome architecture.

2.6 Short branch module (arrowed) abnormally elongated.

2.7 Mean number and length of internodes on long and short rhizome modules.

2.8 Adventitious roots: (a) sinker roots and (b) fine roots.

2.9 Seed and seedling morphology.

2.10 Male spike with anthers exerted.

2.11 Stages in flowering and seed production.

2.12 Defoliation and shading treatments.

2.13 Distribution of the mean aerial dry weight per fertile shoot to component parts under contrasting defoliation and shading treatments.

2.14 Female spikes at the end of the defoliation and shading experiment.

2.15 Mean dry weight per seed under contrasting defoliation and shading treatments.

3.1 Location of the study area.

3.2 Views of the study area.

3.3 Plan view of the study area showing the location of the field sites.

3.4 Panorama of the study area over time.

3.5 The field sites in December 1977.

3.6 Mean monthly (a) rainfall, (b) temperature and (c) windspeed, at sites on the Manawatu plains.

3.7 Percentage frequency of surface wind directions.

3.8 Stratification of the vegetation.
Figure

3.9 Topographic profile of the study area.

3.10 Water table levels in the old deflation hollows over time.


3.12 Soil moisture profiles at five sites on the sand plain, in September 1979.


3.14 Predicted nitrogen fixation rates during primary succession.

3.15 Carex pumila invading the terminal hollow.


3.17 Profile diagram on the edge of the low dune.

3.18 Portions of single genets excavated from the sand plain.

3.19 Statistics of successive sympodial units along primary rhizome axes, at two sites on the sand plain. (a) Total length, (b) total number of internodes and (c) mean internode length per module.

3.20 Statistics of long sympodial units at five sites on the sand plain, in September 1979. (a) mean length (b) mean number of internodes and (c) mean internode length.

3.21 Rhizome diameter.

3.22 Litter bag on an old deflation hollow on the sand plain.

3.23 Decomposition of Carex pumila leaf litter over time.

4.1 The sum of the density of vegetative, fertile and dead shoots of Carex pumila at fosites on the sand plain, in January 1978.

4.2 The sum of the density of vegetative and fertile shoots of Carex pumila over time at four sites on the sand plain, during 1978, 1979 and 1980.

4.3 The sum of the density of dwarf and long shoot populations of Carex pumila over time at four sites on the sand plain between July (winter) and December (summer) 1980.

4.4 Views of the low dune showing newly deposited sand, (a) in spring 1979 and (b) in autumn 1980.

4.5 Area of green leaves of vegetative shoots of Carex pumila over time at four sites during summer 1979-80.

4.6 Frequency distribution of the number of leaves per dead shoot in September 1979.
Figure

4.7 Frequency distribution of shoot age (ratio of the number of dead to total living plus dead leaves) at harvests during 1979 and 1980.

4.8 The sum of the sward mass of Carex pumila and other species, at each of four sites on the sand plain in January 1978.

4.9 The sum of the herbage mass of vegetative, fertile and dead shoots of Carex pumila at four sites on the sand plain, in January 1978.

4.10 (a) The mean dry weight per aerial shoot module of Carex pumila at four sites on the sand plain in January 1978, for (i) vegetative, (ii) fertile and (iii) dead shoots.

4.10 (b) The mean dry weight per branch module (aerial plus underground parts) of Carex pumila at four sites on the sand plain in January 1978, for (i) vegetative and (ii) fertile shoots.

4.11 The sum of the aerial biomass of fertile and vegetative shoots on the sand plain, during 1978 and 1979.

4.12 The aerial biomass of fertile shoots of Carex pumila (grams DM / shoot module) over time at four sites on the sand plain, during two consecutive summers, 1978-79 and 1979-1980.

4.13 The sum of the biomass of fertile and vegetative shoots of Carex pumila at four sites on the sand plain, during 1979 and 1980.

4.14 The ratio of the biomass of living to total living plus dead shoots on the sand plain over the duration of the study.

4.15 The sum of the biomass of dwarf and long shoot populations of Carex pumila over time at four sites on the sand plain between July (winter) and December (summer) 1980.

4.16 The sum of the biomass of component parts of (a) dwarf and (b) long branch modules of Carex pumila (g DM / shoot) on the sand plain in July, October and December 1980.

4.17 The mean aerial dry weight per shoot of dwarf (D) and long (L), fertile (F) and vegetative (V) shoot modules of Carex pumila at four sites on the sand plain in December 1980.

4.18 The effect of hares grazing. (a) View of the edge of the low dune and (b) frequency distribution of leaf length in spring 1980.

4.19 The relationship between annual net biomass accumulation and standing biomass of Carex pumila (a) before and (b) after a 12-th period of biomass accumulation.

4.20 Percent crude total nitrogen content of seeds over four consecutive summers at various sites on the sand plain.

4.21 The distribution of the total nitrogen content of the sward mass at four sites on the sand plain in January 1978.

4.22 The distribution of the total nitrogen content of the standing shoot population of Carex pumila to component parts, at four sites on the sand plain in three successive years (a) 1977-78, (b) 1978-79, (c) 1979-80.
4.23 Stage of development of fertile shoots of Carex pumila (a) over time at two sites on the sand plain, during summer 1979-80 and (b) on the low dune.

4.24 Green leaf area (cm / shoot) of fertile shoots.

4.25 Mean seed weight of Carex pumila over time at three sites on the sand plain during summer (a) 1978-79 and (b) 1979-80.

4.26 Mean dry weight per inflorescence of Carex pumila over time at three sites on the sand plain, during summer (a) 1978-79 and (b) 1979-80.

4.27 Mean number of spikelets (seeds) per inflorescence of fertile shoots of Carex pumila over time, at three sites on the sand plain, during summer (a) 1978-79 and (b) 1979-80.

4.28 Mean number of female spikes per inflorescence over time at three sites on the sand plain, during summer 1979-80.

4.29 Mean number of spikelets (seeds) per female spike over time at three sites on the sand plain, during summer 1979-80.

4.30 Seasonal maximum mean dry weight of seeds per inflorescence in four consecutive summers at various sites on the sand plain.

4.31 Seasonal maximum mean dry weight per seed of Carex pumila in four consecutive summers at various sites on the sand plain.

4.32 Seasonal maximum mean number of seeds per inflorescence on fertile shoots of Carex pumila in four consecutive summers at various sites on the sand plain.

4.33 The frequency distribution of the stage of development of fertile shoots in February 1980, on sheltered and control plots.

4.34 Proportional allocation of dry weight and total nitrogen of the sward mass of Carex pumila to aerial and underground components, at each of four sites (S1, S2, S3 and S4), in summer (a) 1977-78 and (b) 1978-79.

4.35 The proportion of the total nitrogen content of the sward mass of Carex pumila found in vegetative, fertile and dead shoots, at four sites in summer 1979-80.

4.36 Proportional allocation of biomass of fertile shoots of Carex pumila to component parts over time, in (a) 1978-79 and (b) 1979-80.

4.37 Proportional allocation of aerial biomass of fertile shoots of Carex pumila to component parts in mid-summer in four consecutive seasons.

4.38 Proportional allocation of dry weight and total nitrogen of fertile shoot populations of Carex pumila to component parts, in December 1979.

4.39 Ratio of density of fertile to vegetative shoots at four sites on the sand plain, in January 1978.
Figure.

4.40 Proportional allocation of aerial biomass of Carex pumila to vegetative shoots (ABV) and to vegetative (AVR) and fertile fractions of reproductive shoots in four consecutive seasons.

4.41 Proportional allocation of aerial biomass of dwarf and of long shoots of Carex pumila to component organs, averaged over four sites in July 1980.

4.42 Proportional allocation of biomass of (a) dwarf and (b) long branches of Carex pumila to component organs in July, October and December 1980.

4.43 The distribution of biomass of the sward to Carex pumila and to other species with and without nitrogen fertilizer in December 1980.

4.44 Effect of nitrogen fertilizer on the distribution of (a) dry weight and (b) total nitrogen content of Carex pumila biomass to component organs at two sites in summer 1980-81.

4.45 The effect of nitrogen fertilizer on the vegetation on the low dune.

4.46 The effect of nitrogen fertilizer on the number of leaves per shoot, in December 1980.

4.47 The effect of nitrogen fertilizer on the proportional allocation of biomass of component shoot populations of Carex pumila to component organs, in December 1980.

4.48 The effect of nitrogen fertilizer on the proportional allocation of aerial biomass of component shoot populations of Carex pumila to component organs, in December 1980.

4.49 The effect of nitrogen fertilizer on the stage of development reached by fertile shoots, in December 1980.
LIST OF TABLES

2.0 Stages of development of fertile shoots of *Carex pumila* (after Waldren and Flowerday, 1979).

2.1 Dry weight of seeds (utricles) per shoot.

2.2 Number of seeds per shoot.

2.3 Dry weight per seed (utricle).

2.4 Percentage of utricles containing mature nuts.

2.5 Analysis of variance.

2.6 Reproductive effort as a proportion of (a)aerial and (b)total biomass of fertile shoots.

2.7 Parameters of shoots under contrasting defoliation and shading treatments.

2.8 Contributions to propagule weight in *Carex pumila*.

3.1 Wind speed at four sites on the sand plain under two treatments (with (S) and without (C) shelter).

3.2 Percentage cover at five sites on the sand plain in November 1980.

3.3 Mean summer water table levels at six sites on the sand plain, November 1978 to February 1979.

3.4 Percentage of total oven dry weight of various particle size classes of sand at 0-100 mm depth at three deflation hollow sites on the sand plain.

3.5 Soil pH at five sites on the sand plain in spring 1978 and 1980.

3.6 Available nutrient status and percentage carbon, organic matter and nitrogen of the soil at five sites on the sand plain, in September 1978.

3.7 Rates of acetylene reduction and corresponding values for N-fixation of soil and unialgal saes from a moist sand slack on the Manawatu coastal dune system, September 1979.

3.8 Characteristics of excavated portions of *Carex pumila* genets in winter 1980.

3.9 Spread of the clone into the terminal hollow over time.

3.10 Mean length and time of initiation of growth of successive long branch units on a genet excavated from the terminal hollow in July 1980.

3.11 Outline of the procedure to determine the decomposition rate of *Carex pumila* leaves using litter bags in a deflation hollow on the sand plain.
Table

3.12 Decomposition parameters for *Carex pumila* leaf litter.

3.13 Observed and predicted values of $Y$ ($\ln \frac{Wt}{Wo}$), standard deviations of $Y$, residuals and standard residuals for *Carex pumila* leaf litter.

4.1 Change in vegetative shoot density in autumn and in winter 1978 at four sites on the sand plain, relative to the combined fertile plus vegetative shoot density at these sites in January 1978.

4.2 Mean density of fertile shoots *Carex pumila* at five sites on the sand plain, in four consecutive summers.

4.3 Mean age of *Carex pumila* shoot populations.

4.4 Mean dry weight per rhizome segment attached to fertile, vegetative and dead shoots at four sites on the sand plain in summer 1979-80.

4.5 Mean dry weight per rhizome segment, December 1980.

4.6 Mean dry weight per unit length (g/m) of rhizome segments attached to living and dead shoot modules at five sites on the sand plain, in spring 1979.

4.7 Net accumulation of biomass of *Carex pumila* at sites S0, S1, S2, S3 and S4 between successive harvests.

4.8 Estimates of aerial shoot growth rates of long and dwarf shoots at sites on the sand plain during spring and early summer 1980.

4.9 Rates of leaf emergence and increase in leaf length at S0, between August and October 1980.

4.10 Estimated rates of annual net biomass accumulation of *Carex pumila* at five sites on the sand plain, during 1978, 1979 and 1980.

4.11 Analysis of variance of the regression of standing biomass on annual net biomass accumulation.

4.12 Mean seasonal maximum aerial dry weight per shoot module of reproductive shoot populations of *Carex pumila* at five sites on the sand plain, in each of four summers.

4.13 Seasonal minimum and maximum mean dry weights per aerial shoot module of the vegetative shoot populations of *Carex pumila* at five sites on the sand plain.

4.14 Sward mass (grams DM/m²) of species other than *Carex pumila* in 1979-80 and 1980-81 at two sites on the sand plain.

4.15 Mean energy values (joules / gram DM) of component parts of *Carex pumila* shoots.

4.16 Mean elemental concentrations of component parts of *Carex pumila* in October 1978.
Table

4.17 Percent crude total nitrogen values for component parts of live and dead branch modules of Carex pumila, averaged over four sites, in summer 1979-80.

4.18 Percent crude total nitrogen values for component parts of live and dead branch modules of Carex pumila.

4.19 Percent crude total nitrogen values for component parts of vegetative and fertile Carex pumila shoots in December 1980.

4.20 Analysis of variance of percent total nitrogen content of component organs of Carex pumila.

4.21 Mean percent crude total nitrogen values for plant species other than Carex pumila found on the sand plain.

4.22 Total nitrogen content of aerial biomass of Carex pumila during 1978.

4.23 The dry weight and total nitrogen content of component organs of fertile shoots per unit area, at S1 and S2 in December 1979.

4.24 Total nitrogen content (grams N per unit area) of the aerial biomass of Carex pumila at five sites on the sand plain between 1977-78 and 1980-81 (summer means).

4.25 Total nitrogen content of species other than Carex pumila.

4.26 Mean number of spikelets per female spike on fertile shoots of Carex pumila at four sites on the sand plain, in December 1979, (a) on the most distal and most basal female spikes on the culm and (b) on inflorescences with different numbers of spikes.

4.27 Estimated parameters of seed shed at various sites on the sand plain in late summer (a) 1977-78 and (b) 1978-79.

4.28 Regression equations used to estimate seed number per female spike (y = seed number per spike; x = spike length), in 1979-80.

4.29 Mean loss of seeds (number and dry weight) from December 1979 to (a) early January 1980 and (b) early February 1980.

4.30 Effect of shelter on fertile shoot development.

4.31 The effect of shelter on (a) mean spike length and (b) mean number of seeds/spike in December 1979 and (c) mean number of seeds/spike at S2 over time.

4.32 Proportional allocation of biomass of Carex pumila to component parts over time.

4.33 Proportional allocation of total nitrogen of Carex pumila biomass to seeds, rhizomes of vegetative shoots and the sum of the two (a) in December 1979 and (b) in December 1980.

4.34 Proportional allocation of biomass of fertile shoots of Carex pumila to component organs in December 1980.
4.35 Proportional allocation of total nitrogen (TN) and dry weight (DW) of the aerial biomass of fertile shoots of Carex pumila to component parts, summer 1977-78 and 1978-79.

4.36 Ratio of the biomass of dwarf to total (dwarf plus long) branches of Carex pumila at four sites in July, October and December 1980.

4.37 Proportion of the total nitrogen content of the biomass of Carex pumila allocated to dwarf and to long branches at four sites in December 1980.


4.39 Analysis of variance of seed reproductive effort as a proportion of aerial biomass of fertile shoots attached to dwarf and to long rhizome segments, in December 1980.

4.40 Total reproductive effort as a proportion of aerial biomass of fertile shoots attached to dwarf and to long rhizome segments, in December 1980.

4.41 Analysis of variance of the proportion of aerial biomass of fertile shoots attached to dwarf and of long rhizome segments in dead leaves, in December 1980.

4.42 Shoot and shoot bud densities at S0, S1, S2 and S3 on the sand plain, in December 1980, with (N) and without (C) nitrogen fertilizer addition.

4.43 The effect of nitrogen fertilizer on the %TN of component parts of Carex pumila shoots at two sites on the sand plain.

4.44 The effect of nitrogen fertilizer addition on the ratio of dwarf shoots to total (long plus dwarf) shoots; (a) density, (b) total biomass and (c) aerial biomass.

4.45 The effect of nitrogen fertilizer addition on (a) total and (b) aerial biomass of component shoot populations of Carex pumila on the sand plain, in December 1980.

4.46 Mean dry weight per unit area of component organs of Carex pumila populations in table 4.45.

4.47 The effect of nitrogen fertilizer on mean dry weight per branch module of component parts of Carex pumila shoots, in December 1980.

4.48 The effect of nitrogen fertilizer addition on (a) mean seed weight, (b) mean number of seeds per inflorescence and (c) total nitrogen content of seeds of Carex pumila on shoots attached to dwarf and long rhizome branches, in December 1980.

4.49 The effect of nitrogen fertilizer (N) on the proportional allocation of biomass based on (a) dry weight and (b) total nitrogen to component shoot populations, in December 1980.

4.50 Effect of nitrogen fertilizer (N) on the proportional allocation of biomass based on (a) dry weight and (b) total nitrogen of Carex pumila to component organs, in December 1980.
Table

4.51 The effect of nitrogen fertilizer on the proportional allocation of biomass of (a) dwarf and (b) long vegetative shoot populations of Carex pumila to rhizomes, in December 1980.

4.52 The effect of nitrogen fertilizer (N) on the proportional allocation of aerial biomass of (a) dwarf and (b) long vegetative shoots of Carex pumila to component organs, in December 1980.

4.53 Proportional allocation of dry weight and of total nitrogen of the aerial biomass of fertile shoots of Carex pumila to seeds, with and without nitrogen fertilizer in December 1980.