The University of Manitoba Field Station Delta Marsh

1973 Annual Report Number 8

We wish to extend our appreciation to
Dr. H. Albert Hochbaum for the cover illustration.

THE UNIVERSITY OF MANITOBA FIELD STATION (DELTA MARSH)

E I G H T H A N N U A L R E P O R T

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Division of Biological Sciences
The University of Manitoba
Winnipeg, Manitoba R3T 2N2

April 1974

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Director's Report for 1973

Introduction

The University Field Station has taken on a dual role by maintaining both an active research program and providing educational services to University students, high schools and the general public. If natural resources like the Delta Marsh are to be maintained and managed to yield their maximum benefits, basic ecological information must be gathered and its significance disseminated as widely as possible. By combining research and education, the Station endeavors to meet these objectives.

During 1973 the Station increased its already active program in research and teaching. For example, it was used for 454 resident weeks, an increase of 11% over 1972. The participants included:

Staff

Dr. J. Gee (Acting Director)
Dr. J. M. Shay (Director)
J. Evans (Botany)
Dr. G. Robinson (Botany)
Dr. C. Tudorancea (Zoology)

Assistants

M. Danielson
M. Knight
W. Lysack
L. Nostedt
M. Rayner
P. Simonson
H. Smart
T. Wallis

Graduate Students

S. Bates (Zoology)
G. Girman (Botany)
N. Hooper (Botany)
R. McArthur (Zoology)
E. E. Mowbray (Botany)
G. Mutch (Zoology)
E. Pip (Botany)

Support Staff

B. Wallis (Administrator)
N. Mulder (Manager)
G. Mulder (Housekeeper)
I. Garnham (Cook)

Our facilities were used for short periods by Dr. M. Aleksiuk (Zoology), Dr. T. Booth (Biology Teaching Unit), Dr. R. Green, R. Pauls and T. Stewart (Zoology) in relation to their research. We were pleased to welcome Dr. C. Tudorancea (Faculty of Biology, University of Bucharest) who joined the staff as a Post-doctoral Fellow in April to study benthic fauna in Lake Manitoba. His investigations will continue until September 1974.

Research

Ten research projects were based at the Station in 1973; of these

four were continued from the previous year, four began in the summer and two in the fall. The projects covered a broad spectrum of inquiry into the structure and function of the marsh and lake habitats. They included mapping the vegetation of the marsh, the response of several marsh species to differing water levels, the effects of prescribed burning on *Phragmites communis*, primary productivity of epiphytic algae on macrophytes, the impact of pesticides on plankton in the marsh and lake, plant-snail interactions, the productivity of the lake's benthic fauna, population biology of the leopard frog, winter ecology of the striped skunk and energetics of the muskrat.

We congratulate A. J. Macaulay who in December successfully completed his Ph.D. thesis on "Taxonomic and ecological relationships of *Scirpus acutus* and *S. validus* in southern Manitoba."

Teaching

Four two-week 1/2 credit courses were held during the Summer Session with a total enrollment of 38:

Introductory Ecology (Botany 1.336 or Zoology 22.229) was given by Dr. R. Longton (Botany) and Miss S. Behrens (Zoology, University of British Columbia), assisted by K. Machniak. Students studied the principles governing the structure and function of ecosystems with particular reference to marsh plant and animal communities.

Ecology (Zoology 22.334) was led by Miss S. Behrens, assisted by K. Machniak. Topics included the characteristics of populations, the effect of environment on the distribution and abundance of animals, ways in which animal numbers are regulated and interactions between species.

Ornithology (Zoology 22.468) was offered for the first time. Dr. S. Sealy (Zoology) and students examined aspects of bird biology in relation to the natural environment with the emphasis on field studies.

Plant Ecology (Botany 1.452) was under the guidance of Dr. J. M. Stewart (Botany). Students applied a variety of current descriptive and classificatory methods to plant communities at Delta Marsh and the Spruce Woods Provincial Park. This course ran concurrently with *Ornithology*.

The Station was also used for weekend field work by Dr. R. Brust (Entomology 38.419) and Dr. J. M. Stewart (Botany 1.338). We were pleased to have two visits from Dr. R. Moodie and students from the Department of Biology, University of Winnipeg, one in October and the other in February.

Seminars

The weekly summer program was arranged by Mrs. J. Evans, and we thank the following speakers for their interesting and stimulating presentations: Miss S. Behrens (University of British Columbia), Dr. T. Booth (Biology Teaching Unit), Dr. G. Calef (Templeton Engineering), Dr. J. Henderson (Pathology), Dr. R. Longton (Botany), Dr. R. Riewe (Biology Teaching Unit), Dr. G. G. C. Robinson (Botany), Dr. S. Sealy (Zoology) and Mr. R. Taylor (Manitoba Museum of Man and Nature).

The Seventh Annual Seminar was held on November 22; seven papers were presented and accompanied by useful discussion. The audience of more than 50 included members of the Department of Mines, Resources and Environmental Management, Ducks Unlimited, Delta Waterfowl Research Station, The Manitoba Museum of Man and Nature and Councillors from the Rural Municipality of Portage la Prairie.

High School Visits

A series of day-visits for senior high school groups took place during May and June, and 450 students visited the Station. We were fortunate to have Miss H. Smart, a second-year Zoology student, as instructor. She was funded by the STEP Program, to whom we are grateful for their assistance in this new venture. Each group (15-20) was introduced to marsh ecology by a nature walk and field exercises. We hope to continue the program in 1974, with the field exercises integrated with the school curriculum so that data gathered can be utilised later.

As part of Project Canada West, Mr. A. Watson and a group of 19 students from John Taylor Collegiate spent 13 days at the Field Station in May studying marsh ecology and filming their field activities.

Adult Education

A series of weekend courses were organised in conjunction with Community Studies, Extension Division, University of Manitoba. On the whole the series was successful although, due to lack of participants, three of the summer weekends were cancelled.

The weekend courses held were:

February 23-25	Human Survival in Winter	Dr. R. Riewe
April 20-22	Spring Waterfowl Migrations	Mr. B. Batt
May 4-6	Wildlife Photography	Mr. R. Taylor
September 21-23	Marsh Ecology	Dr. R. Nero

Our facilities were used for short periods by the departments of Education and Architecture who held study weekends at the Station. A group of Canadian environmentalists met for a two-day workshop in October

to discuss a Canadian "Blueprint for Survival." This session was sponsored by the Agassiz Centre for Water Studies and the Canada Council.

We were pleased to welcome a number of visitors at various times during the summer, including President E. Sirluck and Mrs. Sirluck.

Facilities

In the spring one of the housing units acquired last year was renovated to provide dormitory accommodation for 17, and the kitchen in Criddle was transformed into a double bedroom, allowing us to accommodate 45 plus five married quarters.

Rewiring and minor renovations in the Agassiz lab have produced three teaching laboratories, each able to house 15 students, and three small research laboratories. Major items of equipment will be kept in the middle teaching lab in the hope that centralising equipment will be of benefit to all users.

There were some problems regarding the use of the Station property by fishermen, trappers and deer hunters because of conflicts with present and future research projects. Muskrat, skunk and deer population studies cannot be carried out effectively if unauthorised persons come into the area and trap them. The dumping of fish offal also has many unforeseen effects. We are fully aware of the need to explain our position to local people and hope that our efforts are being sympathetically received.

Acknowledgements

During my sabbatical leave, Dr. J. Gee served as Acting Director, assisted by Mr. B. Wallis. To them both I extend my sincere thanks for a commendable job. We are again indebted to Manitoba's Department of Mines, Resources and Environmental Management for financial assistance in many of our projects and for their continuing interest in all our activities. The Portage Country Club has allowed us to expand our use of their property and their generosity is gratefully acknowledged. Finally I extend my appreciation to all the staff and students who have helped to make the Field Station a "going concern."

J. M. Shay
Director

April, 1974

Population Dynamics of Leopard Frogs (*Rana pipiens pipiens*) at Delta Marsh

S. Eddy

Department of Zoology

Introduction

The northern leopard frog, *Rana pipiens pipiens*, is distributed generally in southern Manitoba at least as far north as the northern ends of Lakes Winnipeg and Winnipegosis. It is basically a frog of marshes and wet meadows, and, unlike most other anurans in the province, it overwinters under water. This effectively limits its local distribution to areas near permanent water bodies which provide overwintering sites.

The marshes surrounding the southern margins of Lakes Winnipeg and Manitoba probably harbour the densest and most extensive populations of leopard frogs in the province. These areas also provide habitat for large numbers of waterfowl, wading birds and semiaquatic mammals. In these areas, amphibians in general, and the leopard frog in particular, because of its large populations, constitute an important component of the ecosystem. Between late May and early July, the larvae constitute a large body of primary grazing animals, feeding on algae and higher aquatic plants. During the entire active season, from early May to late September, the adult leopard frogs are consuming larval and adult insects. Both larval and adult leopard frogs are eaten by other predators in the marshes, including wading birds, skunks, mink and weasel.

In addition to the intermediate trophic position of the leopard frog, the species is also of some commercial importance in the biological supply trade. During 1973, 50 tons of leopard frogs were collected for this purpose in southern Manitoba (Scott, personal communication).

Because of its trophic position in marsh ecosystems and because of the increasing pressure of commercial collecting on leopard frog populations in southern Manitoba, the Manitoba Department of Mines, Resources and Environmental Management has supported a study of the population ecology of the leopard frog. Starting in May 1972, this study has been directed primarily at determining the size/age structure of a leopard frog population, its rate of egg production and survival rates of larvae. In addition, descriptive data have also been gathered on larval and adult distribution and habitat as it varies during the active season. Individual and group toe-clip markings have provided some data on adult movements and return to breeding areas.

Although population dynamics have been studied for several anuran species, almost no work has been done on *Rana pipiens*. Growth of adult *R. pipiens* was followed in individual marked and recaptured frogs by Ryan (1953) with a sample of 26 frogs. Merrell (1968), in determining the role of genetic drift in the distribution of the non-spotted burnsi gene, determined that the "effective population size" or the breeding frogs in a Minnesota *R. pipiens* population was far smaller than the actual number of adult frogs.

Population structures of adult frogs have been studied for *R. clamitans* (Martof, 1956a), *R. aurora* (Calef, 1973a) and *R. pretiosa pretiosa* (Turner, 1960). Ryan (1953) has studied growth rates of *R. pipiens*, *R. clamitans* and *R. catesbeiana*. Tadpole survival has been studied in *R. aurora* (Calef, 1973b), *R. clamitans* (Martof, 1956b), *R. pretiosa* (Turner, 1960) and *R. sylvatica* (Herreid and Kinney, 1966). Many of these studies can be compared to the Lake Manitoba *R. pipiens*, but there are differences not only between species, but also between different populations of the same species.

Methods and Materials

The Study Area

The project was conducted on the University of Manitoba Field Station property at Delta Marsh, Manitoba. This is a portion of the continuous marshland which surrounds the southern end of Lake Manitoba, extending from approximately St. Laurent at the eastern extreme to the mouth of the Whitemud River on the west, a distance of about 47 km.

Leopard frogs are continuously distributed over this area during the active season. Overwintering is in Lake Manitoba, as is shown by mass movements of leopard frogs out of the lake and into the marsh each spring and reverse movement in the fall. These movements cross roads which run parallel to the lake shore on the sandy ridge separating the lake from the marsh and are part of local historical knowledge. Leopard frogs are also caught frequently in gillnets as much as 20 km offshore during the winter commercial fishing season on Lake Manitoba.

Because of the above, leopard frogs inhabiting this area probably constitute one continuous population. Although there is no commercial exploitation of leopard frogs on the Field Station property, they are intensively collected elsewhere in the marsh, so the population studied here is considered to be exploited.

There were three study areas used in the two summers 1972 and 1973, chosen from sites where breeding behaviour was observed. The first was a wet meadow area near the west dike of the Assiniboine River Diversion. The wet area was surrounded by *Scolochloa festucacea* with emergent *Typha* sp. and *Scirpus* sp. bordering directly the deeper water. Water in the area was up to one meter deep in May 1972. In 1973 it was dry and thus abandoned as a study area.

A second area, which was used more extensively to study larval development, was the northeast end of the Blind Channel, which is connected to Lake Manitoba via Cram Creek and man-made ditches. The channel is bordered mainly by *Typha* sp. in the area where breeding activity occurred, and the bottom was covered in both years with *Myriophyllum* sp. by late summer. The easternmost last km of the channel was monitored carefully for eggs and tadpoles, but, in both years, they were confined to the easternmost 150 m of the channel.

The third study area was a small L-shaped ditch, with a total length of about 190 m, connected to the Blind Channel but blocked off from it by a net of 1/4-inch mesh across a culvert shortly after the tadpoles hatched. The vegetation around and in the ditch is more varied than for the other two areas. *Phragmites communis*, *Typha* sp., *Urtica dioica*, *Agropyron repens*, *Cirsium arvense* and *Salix* sp. are among the most frequently occurring plants along the banks of the ditch, and *Myriophyllum* sp., *Potamogeton pectinatus* and *Potamogeton richardsonii* cover most of the bottom.

Collecting Methods

Adult frogs were caught by hand nearly daily throughout both seasons. During the spring and fall migrations, a drift fence was built between two of the Field Station buildings at the top of the beach ridge. Pitfall traps were sunk at each end of the fence to monitor movement in both directions as well as to aid in capturing a large sample. During the rest of the season, frogs were caught by hand or with the aid of dipnets. Until metamorphosis, the sample seemed to represent all sizes present in the population. After the young-of-the-year had transformed, when adult frogs made up about 2% of the population, the sample was deliberately biased towards the adults in order to obtain a large enough adult sample for size frequency analysis.

Egg masses were located by thorough visual scanning of all the study areas every two or three days. Volume was determined for all egg masses located in 1972 and for a portion of those found in 1973. Subsamples of the egg masses gave an estimate of eggs/ml and percent fertilized. From these subsamples, a total number of viable eggs could be estimated for each area.

Tadpoles were caught mainly by dipnet. Marked recapture enumeration was attempted both years in the ditch, where the population was contained by the net described above. The mark consisted of methylene blue dye injected into the caudal fin. In 1973 traps made of polyethylene bottles with funnels of wire screen were anchored just below the surface of the water on a 75-m^2 grid, 15 m apart in the Blind Channel in the area where eggs and tadpoles had been found. Growth of the tadpoles was followed both in the ditch and in the channel on alternate days from a few days after hatching until most had transformed, a period of about six weeks. Samples of 50 or 100 tadpoles were caught and measured for body and total length. Tadpoles being marked and those caught in traps were also measured.

Results

In order to separate size classes, frequencies were changed to cumulative percent frequency and plotted on probability paper (Figs. 1-4). Inflection points on the resulting curve indicate a trough between two normal distributions (Cassie, 1954). If these are split, recalculated and replotted, they yield straight lines with a mean at the 50% line. This method gives a nearly identical range of size classes for the two years and little difference in range of size classes for males and females. The means and distributions within size classes were quite different between the two years, however.

Female frogs of the 1971 year class (Fig. 5), the first age class for May 1972, grew an average of 23.6 mm over the summer of 1972 and 26.4 mm over the summer of 1973. The third summer's growth seems unusually large and may be an artifact of using average size as an indicator of growth. This same age class suffered tremendous mortality in their second winter, and the proportion of two-year olds is much smaller in May 1973 than in May 1972. In 1972 the large age three frogs did not appear in the September sample, and the two-year olds showed less apparent growth. Probably the high survival of large females indicates that the three-year olds survived the summer of 1973 but not 1972 and may contribute to the breeding population in 1974 as four-year olds.

Size frequency results for male frogs (Fig. 6) are similar in that one and two-year olds are almost absent from the May 1973 sample. On the other hand, means are much smaller for three-year old males than for females, and growth rates are comparable to those in 1972.

Percentages of the total population in each age class were calculated for both sexes in the May sample of each year and the percentage of the adult population for both the May and September samples (Table 1). The two-year olds, some of which were mature and possibly breeding, were severely decreased in number. The one-year olds, an age class which seems to be small anyway, was much smaller in 1973 than in 1972.

Egg deposition took place between 6 and 21 May in 1972 and between 1 and 23 May in 1973, but breeding took place over a shorter time interval in 1973, mainly in the first ten days of calling activity by males. In the Blind Channel the number of egg masses remained constant at 230 from 8 May to 24 May, when hatching began. In 1972 in the channel, all the egg masses found were found clinging to *Typha* just below the surface of the water along the margin of the channel. The water was too deep to observe whether there were eggs on the bottom in 1972, yet all the eggs in the channel were found on the bottom in 1973. These were at depths between 31 and 38 cm. In the ditch, eggs were found in water of the same depths but they were at the surface, attached to emergent vegetation.

Eggs/ml averaged 21.3. Total size of masses ranged from 50 to 620 ml in 1973 and 50 to 180 ml in 1972. The mean size in 1973 was 230 ml, giving a total estimate of 1,086,000 eggs for the 60 x 80 m at the easternmost end of the Blind Channel. The total number of eggs in the ditch in seven egg masses was estimated at 13,000, a far smaller number than the 27,000

nearly grown tadpoles estimated for the same area for 1972. No estimates of egg numbers could be made in 1972 since location of all the eggs in a given area was far less certain. Mortality in the egg stage was estimated at 50% in the wet meadow in 1972, 20% by failure to develop and 30% by physical displacement and/or breaking up of egg masses. Individual egg masses could not be marked in the Blind Channel, so no comparison could be made, but the constant number of egg masses after 8 May was probably maintained by a combination of at least some additional spawning and displacement by wind, fish and other animals.

Tadpole enumeration was more successful in 1972 than in 1973. Estimates in the ditch from marked recapture experiments ranged from 16,000 to 27,000. In 1973, when a repeat of this experiment was attempted, tadpole mortality was very high, and it became impossible to catch enough tadpoles for a meaningful estimate. Dissolved oxygen was measured at 3 ppm at the end of the ditch, where the most tadpoles had been found, apparently too low a concentration for survival.

Mortality of tadpoles was high in the Blind Channel as well. Trapping began after numerous dead tadpoles had been noticed on the surface of the water, but, in the last ten days before transformation, the daily catch dropped 94%. There was a lot of variation in catch due to changing water temperature, and casual observation of high mortality was probably more conclusive than trapping results.

Hatching of eggs was about one week later in 1973 than in 1972 (Fig. 7). Comparatively low May temperatures undoubtedly slowed the development rate of eggs. In 1972 tadpoles grew much faster in the ditch than in the channel. In 1973 the two groups grew at an equal rate and a rate equal to those in the ditch in 1972, but remaining ten days behind until transformation.

Discussion

The winter of 1972-73 had a severe effect on the leopard frog population. Lack of snow before freeze-up resulted in thicker ice than usual on Lake Manitoba and on the marsh. Winter kill seemed high both in casual observation and in shifting size frequencies. The first two size classes were decreased, but the older frogs did not seem to be affected. Precipitation in the fall of 1972 and throughout the winter was extremely low, and many of the disperse breeding sites used in 1972 were dry in 1973. Breeding was confined to the Blind Channel, Cram Creek and the few roadside ditches and borrow pits which had enough water in them.

The reason for the survival of three-year old female frogs in 1973 but not in 1972 is unknown. Cool weather in the early fall probably kept frogs under cover and protected them from predation. Basking weather in 1972 made large, overfed frogs easy prey for the American bitterns, great blue herons, skunks and garter snakes that seemed common in the area. Lack of warm weather for feeding would also help explain the poor overwinter survival of frogs held in the laboratory this winter. A less-

likely explanation for the survival of older frogs in 1973 is relaxed competition for food, but it is extremely unlikely that food is in any way limiting on the population. Whatever the explanation, the largest size class of females is probably a combination of two age classes, three and four-year olds. This would explain an increased mean size. If, as in the females, the older males lived through the summer, they did not show any growth. Individual growth rates will help to clarify the size distribution.

Egg deposition seems to take place in a preferred depth range. The only likely explanation for egg deposition on the bottom, as in 1973, rather than attached to vegetation, is that there was no vegetation near water of a suitable depth. There may be several unknown requirements for breeding sites. Suitable breeding sites were obviously limited in the spring of 1973, and the high tadpole mortality indicated that the sites chosen were inferior.

Large fluctuations in population size and size frequency distribution are common for other ranids, *Rana clamitans* (Martof, 1956a), *R. pretiosa* (Turner, 1960) and *R. temporaria* (Bannikov, 1948), for example. Because the breeding portion of the Lake Manitoba *R. pipiens* population for 1975 and 1976 is already very low, low production can be expected in those years. Production in 1974 is still subject to speculation. Precipitation has been high enough to insure sufficient breeding sites. Overwinter mortality will be high, if frogs held in captivity under simulated overwintering conditions reflect the health of the total population. On the other hand, the frogs appear to have a high reproductive rate, and breeding conditions, egg and tadpole survival are probably far more important than the size of the breeding population in determining the yearly production. Perhaps even the 1975 and 1976 breeding populations will be sufficient for normal production.

Management schemes for harvesting of leopard frogs must take into account the natural fluctuations in population size and structure. Production in 1974, as well as the age structure, should indicate what sort of harvest can be sustained following a year of drought conditions.

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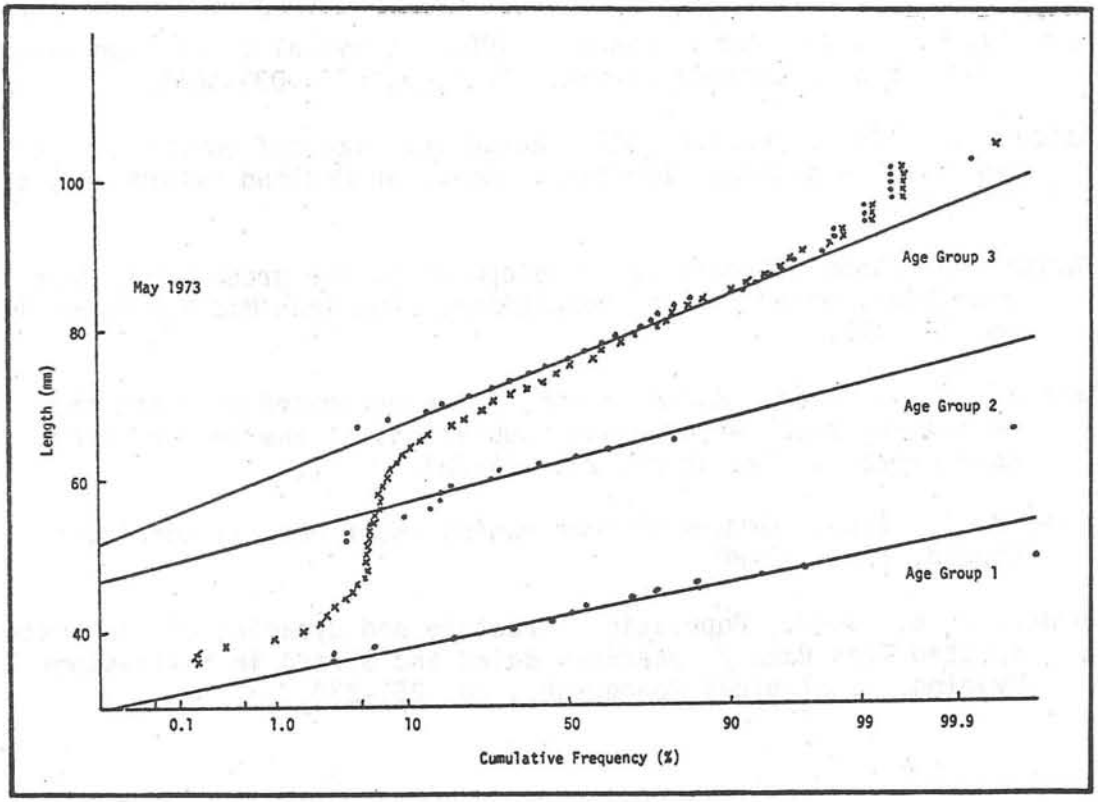


FIGURE 1. Cumulative Frequency of Females by Age Classes in May 1973.

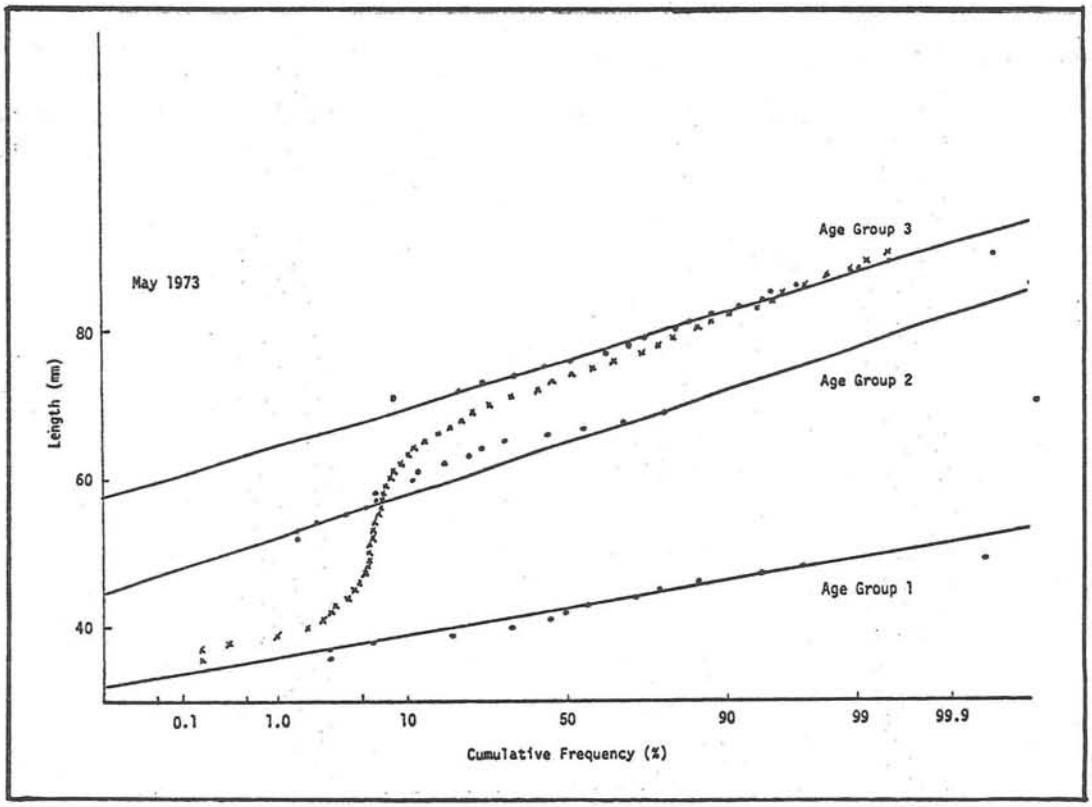


FIGURE 2. Cumulative Frequency of Males by Age Classes in May 1973.

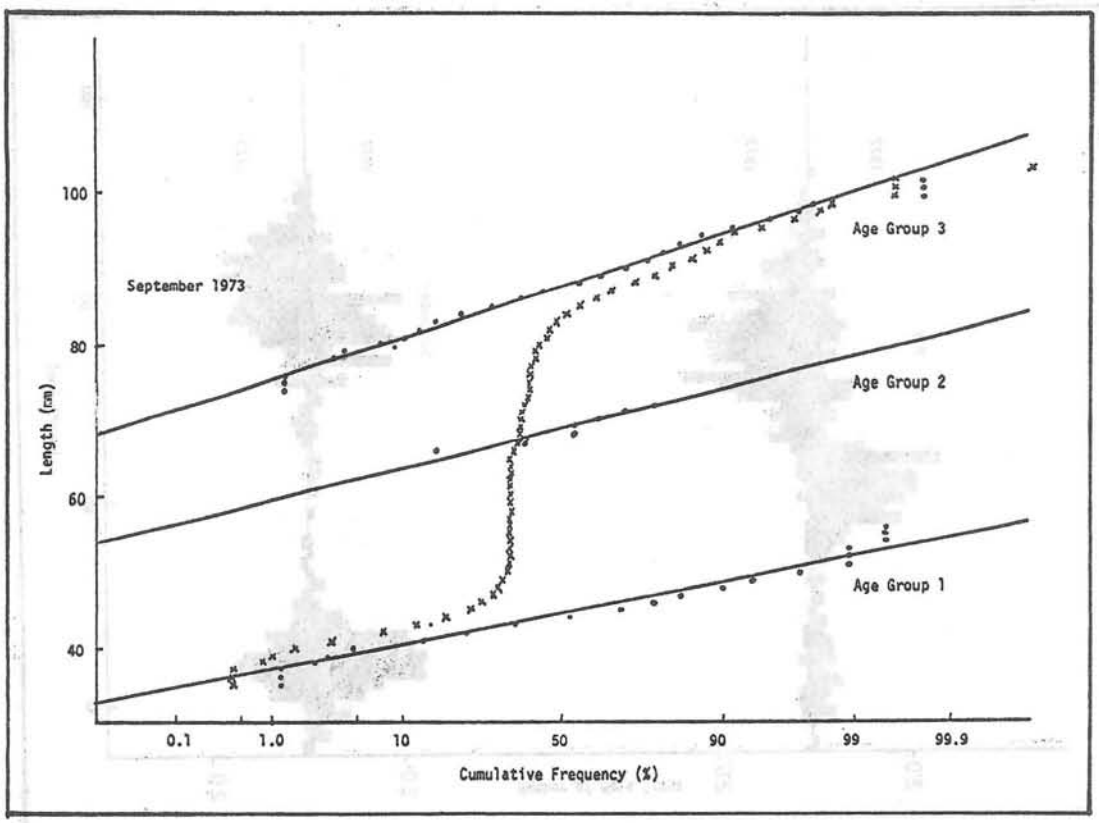


FIGURE 3. Cumulative Frequency of Females by Age Classes in September 1973.

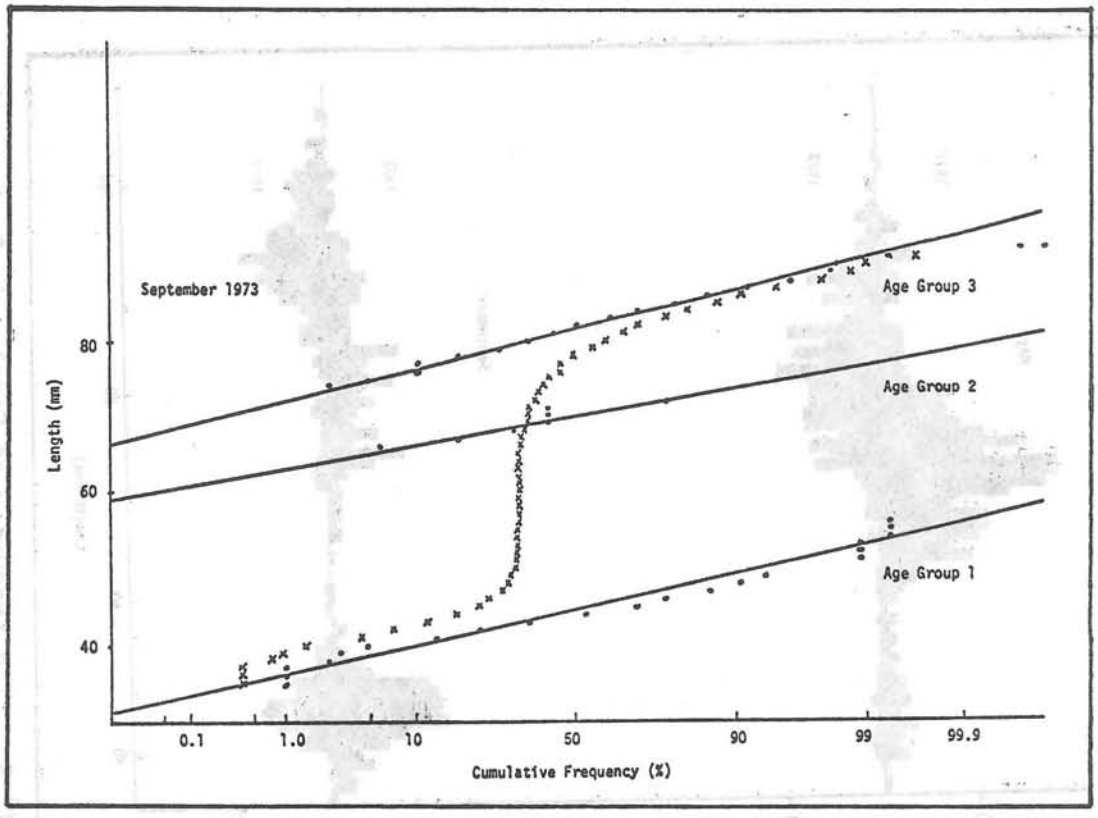


FIGURE 4. Cumulative Frequency of Males by Age Classes in September 1973.

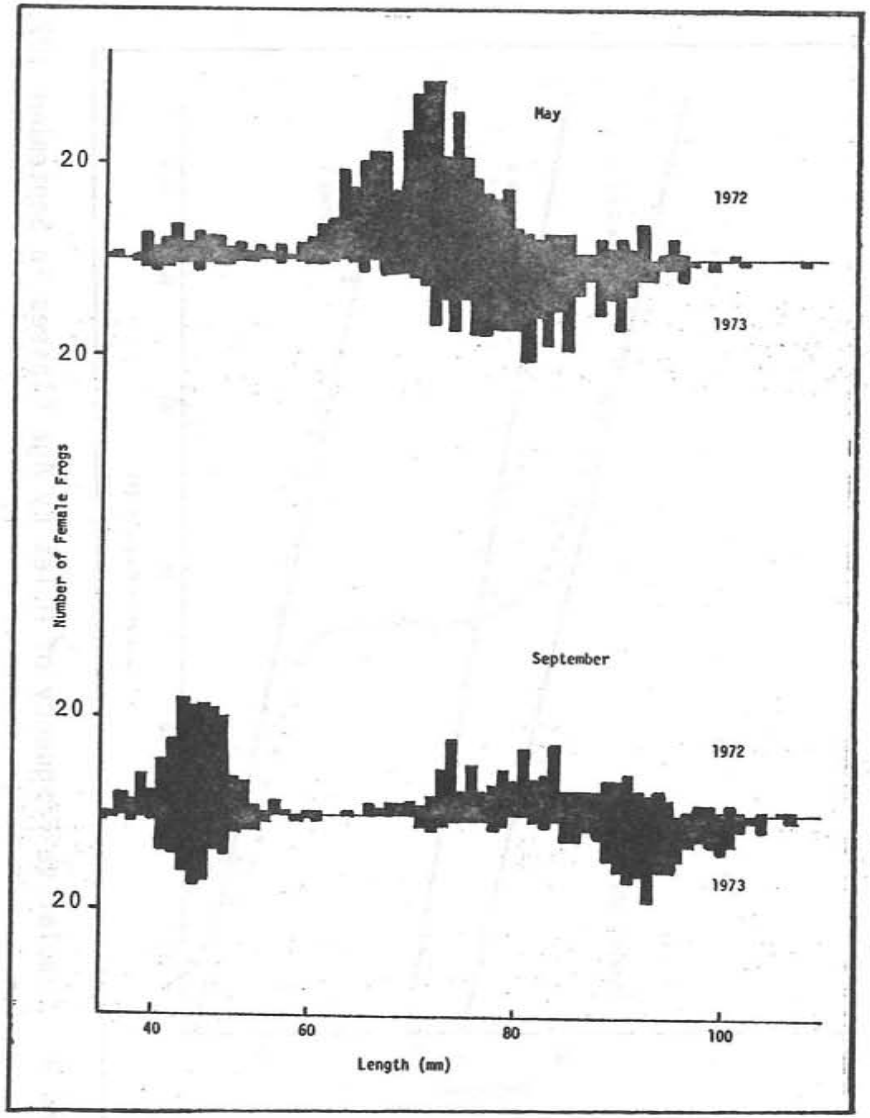


FIGURE 5. Size Frequency of Females in Spring and Fall, 1972 and 1973.

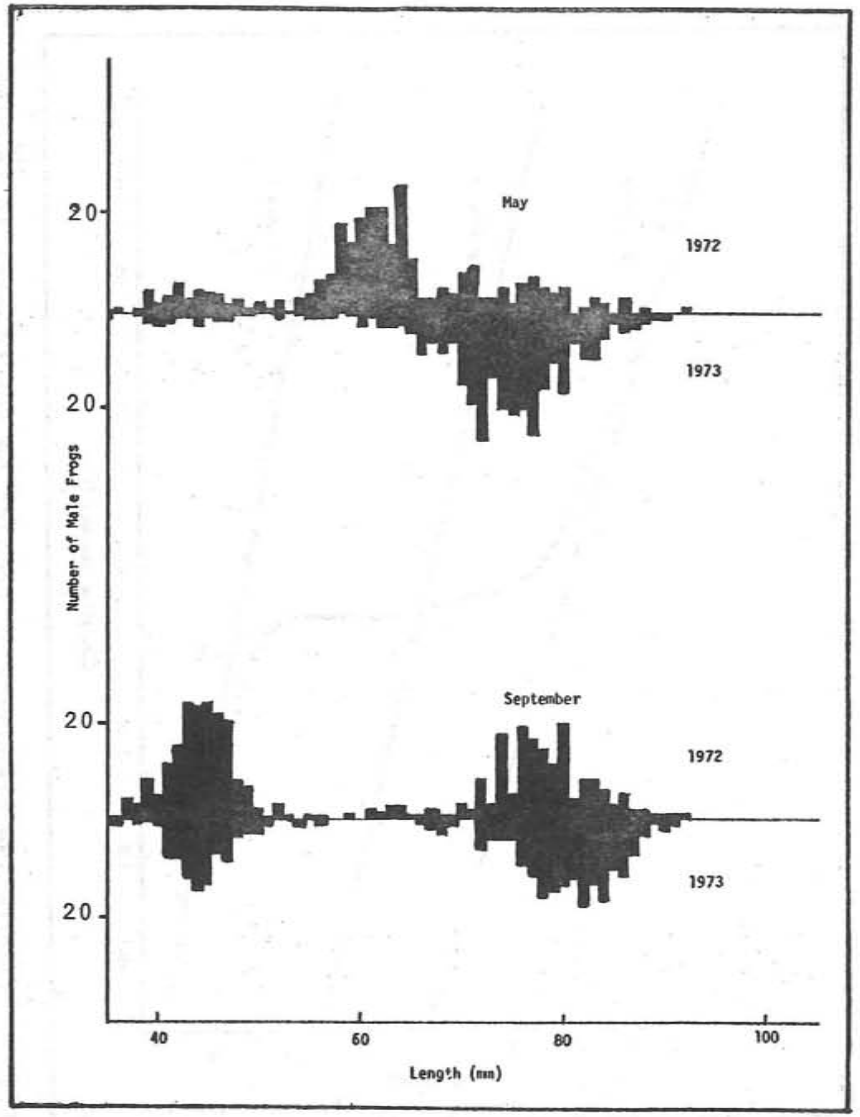


FIGURE 6. Size Frequency of Males in Spring and Fall, 1972 and 1973.

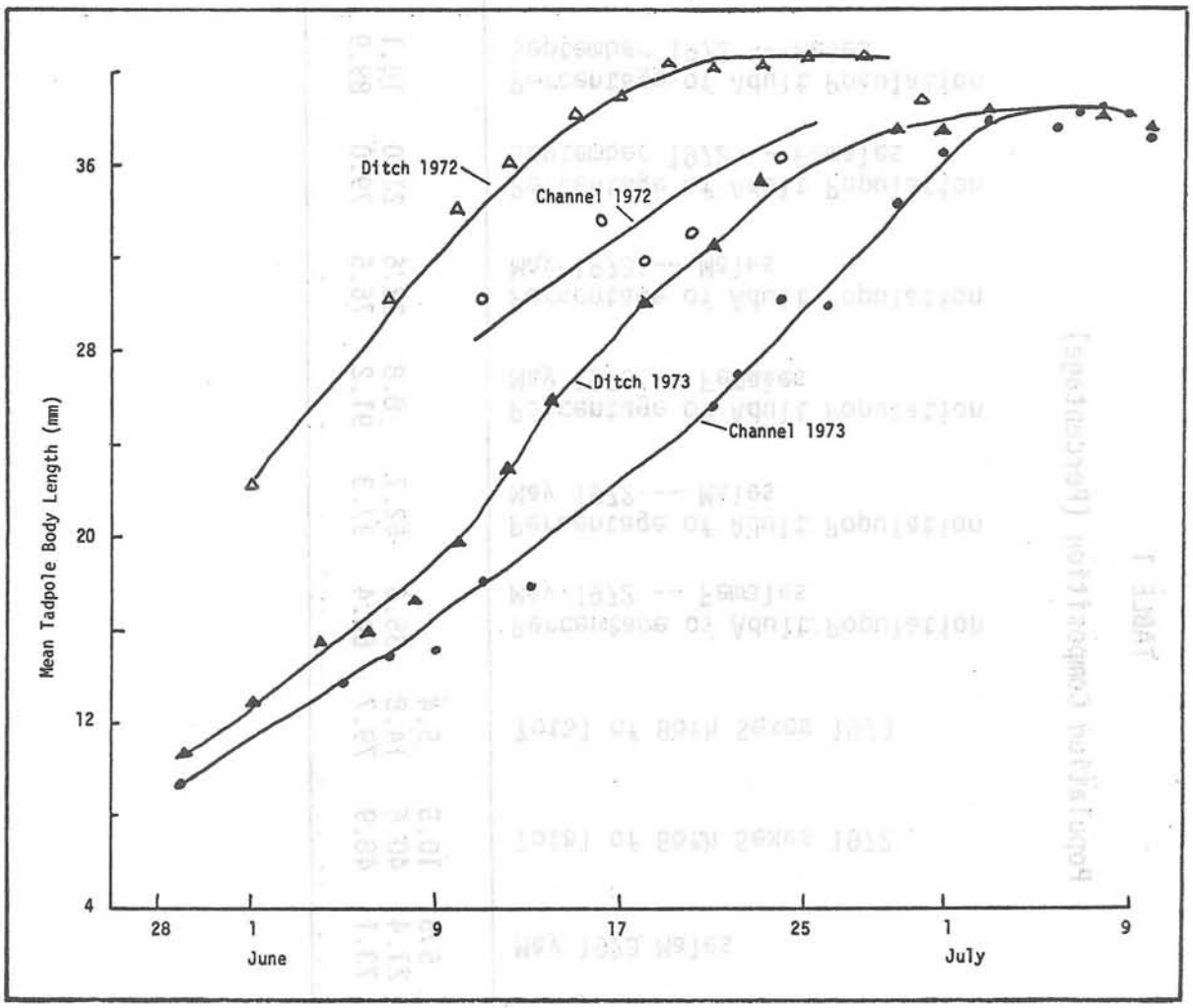


FIGURE 7. Tadpole Growth Rates in Ditch and Channel, 1972 and 1973.

TABLE 1

Population Composition (Percentage)

Age Class	May 1972 Females	May 1972 Males	May 1973 Females	May 1973 Males	Total of Both Sexes 1972	Total of Both Sexes 1973
1	8.4	13.9	5.4	5.5	10.5	5.4
2	32.6	54.0	8.4	21.4	40.6	14.8
3	59.0	32.1	86.2	73.1	48.9	79.7

	Percentage of Adult Population May 1972 -- Females	Percentage of Adult Population May 1972 -- Males	Percentage of Adult Population May 1973 -- Females	Percentage of Adult Population May 1973 -- Males	Percentage of Adult Population September 1972 -- Females	Percentage of Adult Population September 1972 -- Males	Percentage of Adult Population September 1973 -- Females	Percentage of Adult Population September 1973 -- Males
	35.6	62.7	8.8	22.6	21.0	10.1	7.8	9.4
	64.4	37.3	91.2	76.6	79.0	89.9	92.2	90.6

Vegetation Mapping and Analysis in Delta Marsh

J. Evans

Department of Botany

Objectives

The aim of this project was to map the vegetation of the Delta Marsh and to assess changes in vegetation patterns on a seasonal and long-term basis. Such a map is considered important for formulating management plans for wildlife habitat and to provide relevant data for use in devising water regulation regimes within the marsh.

Introduction

Delta Marsh is a complex network of shallow bays and channels of open water separated by vegetation. It is possible to divide the vegetation into distinct communities recognisable on the ground and in aerial photographs. These communities are *Phragmites communis*, *Typha latifolia* and *Scirpus* spp. marshes and *Scolochloa festucacea*, *Sonchus* spp. and *Hordeum jubatum* meadows. Small patches of mixed deciduous woodland and upland prairie are scattered through the marsh on higher ground. To the north, the marsh is separated from Lake Manitoba by a forested Agassiz beach ridge and on the south, the marsh is bounded by farmland.

The last vegetation map of the marsh was prepared in 1965. In October 1972 work commenced on the preparation of a new vegetation map from photographs taken at an altitude of 6,000 feet in August 1972. During the winter of 1972-73, the vegetation was delineated and an interim map produced in March 1973. In the spring and summer of 1973, ground truthing of the communities was undertaken and the ensuing vegetation map is now being prepared for publication. Analysis of changes in vegetation since 1965 is in progress.

Methods

During the summer of 1973, vegetation changes were analyzed using two line transects, one (T1) from the lakeshore south into the marsh for approximately 300 m and the second (T2) from the borrow pit north of the South Marsh Road to the Blind Channel, approximately 260 m (Fig. 1). Each transect was divided into 20-m sections. The vegetation at 50-cm

or 1-m intervals within each section was analyzed on five occasions for T1 and three times for T2. Soil samples were taken from approximately the centre of each section in August and their pH, organic content and moisture content determined. Three replicates were made for each analysis and the results averaged. The transect data are summarized in Figs. 2 and 3.

In addition to the transects, permanent 0.5 x 2-m quadrats were established in each of 21 communities (2 *Phragmites*, 2 *Scirpus*, 2 *Typha* marshes, 3 *Scolochloa*, 3 *Sonchus*, 1 *Hordeum* meadows, 3 borrow pits, 3 woodlands, 2 prairies). These were analyzed for species present in May, June, July and August. Tree species in the woodland sites were sampled by the point quarter method. In August species frequency in each site was estimated using 50 or 100 0.25-m^2 quadrats. Soil analyses for pH, organic content and moisture content were made on samples from each site in May, June, July and August. Three replicates of each analysis were made and the results averaged. Mechanical analysis and estimation of soil colour and texture were made in May.

Analysis of the vegetation and soil data is proceeding and will be presented in a research report to accompany the vegetation map. A brief outline of some of the results follows.

Results and Discussion

Preliminary analysis of the 1972 vegetation map suggests that total percentages of marsh, open water and woodland have remained stable in the part of the marsh studied so far (Table 1). However, the percentage of farmland has increased at the expense of meadow. This is an indication that the area has become drier. If this is so, changes would also be expected in the percentages of marsh communities and open water. The area chosen for the preliminary analysis was the eastern half of the west portion of the marsh and included the University of Manitoba Field Station and Delta Waterfowl Station. This area is bounded on the west by Deep Creek and on the east by the west shore of Cadham Bay. In 1965 this part of the marsh had a considerably lower percentage of open water and a considerably higher percentage of woodland and farmland than the marsh as a whole (Table 2), indicating that this area was drier than much of the marsh at that time. Changes due to lower water levels may be less apparent here.

Continued interpretation of the maps will allow analysis of changes in individual communities and of the changing ratios between marsh and meadow. This should shed more light on the patterns of change within the marsh as a whole and pinpoint the areas where there may be a need for a water regulation regime.

The transect data showed that marsh species, *e.g.*, *Phragmites communis* and *Scirpus acutus*, occupied the areas with the highest moisture content. Wet *Scolochloa* meadow, *Sonchus* meadow, artificial borrow pits and woodland soils had decreasing moisture contents in that order. A similar trend was observed for organic content; pH appeared to be somewhat negatively correlated with moisture and organic content. Marsh species were found where

TABLE 1

Changes in Percentage of Vegetative Cover in the West Marsh (East Half)

	1972	1965
Open water	17.84%	17.66%
Marsh	24.50%	23.12%
Meadow	21.76%	24.73%
Farmland	29.53%	25.35%
Woodland	4.80%	4.33%

TABLE 2

Comparison of Percentage of Vegetative Cover in West Marsh (East Half) and Total Marsh, based on 1965 Vegetation Map

	West Marsh (East Half)	Total Marsh
Open water	17.66%	27.28%
Marsh	23.12%	25.31%
Meadow	24.73%	23.89%
Farmland	25.35%	18.40%
Woodland	4.33%	2.31%

the pH range was low (6.98-7.73), while the pH range was high in the borrow pit (8.26-8.56), *Sonchus* meadow (8.17-8.49) and on the lakeshore (8.30).

From the vegetation analysis of individual communities, it was apparent that the most species-rich communities were the woodlands, prairie site 2 and *Typha* site 1 (18-26 spp.). The poorest were the *Scolochloa* meadows, *Typha* site 2, *Scirpus* marshes and borrow pits 1 south and 2 (2-7 spp.). The *Scolochloa* meadows, *Typha* 2 and the *Scirpus* sites have a very high percentage cover of the dominant species and this would preclude the successful growth of many understory species which cannot tolerate low light intensities. The high alkalinity of the borrow pits inhibits the growth of plants that cannot tolerate high pH and both sites have very sparse vegetation. Soil analysis emphasized the highly alkaline nature of these sites (pH was over 8.3 in May) and the vegetation included a large proportion of halophytes, e.g., *Salicornia rubra, Puccinellia*

nuttalliana, *Scirpus paludosus* and *Chenopodium glaucum* var. *salinum*, in addition to wetland species, such as *Typha latifolia* and *Scirpus acutus*, towards the edges of the pits.

The lowest range of pH was observed in the woodland sites (7.47-8.09 in May). In almost all communities there was a tendency for pH to fall through the summer. Organic content of the soil was lowest in the borrow pit sites and in *Typha* site 1, which represents invasion of *Typha* into an old borrow pit. These values ranged from 1.69-3.25% in August. Highest values (24.34-51.37%) were obtained in the *Scolochloa*, *Phragmites* and *Scirpus* sites and in *Typha* site 2, presumably due to the accumulation of litter each year. There was a slight tendency for organic content to be high in May, fall off in June and increase again towards the end of the summer. However, the results are variable and this trend may be erroneus.

There was considerable variation in soil moisture between sites. The *Scolochloa* meadows, *Phragmites* 2, *Typha* 2, *Scirpus* 2 and the *Hordeum* site had the highest moisture contents (64.66-73.08%). The lowest (6.43-23.79%) were found in the two sparsely vegetated borrow pits 1S and 2 and in the sandy soil of woodland 3. Due to the low snowfall in the winter of 1972-73, water levels in the marsh were very low in May 1973 and this was reflected in the soil moisture figures. Many sites showed an increase in soil moisture in June as the rainfall in the month was high. In the drier meadow, prairie and woodland sites, moisture content fell off in July and August. In the wetter sites, it remained relatively high during July but started to decrease in August.

Variation in species composition between communities of the same types was frequently dependent on surrounding community types, as well as edaphic considerations. For example, prairie site 1, which was bordered by *Phragmites* marsh, had a number of wetland species, *e.g.*, *Triglochin palustris*, *Eleocharis palustris* and *Spartina pectinata*, in addition to prairie and dry meadow species, such as *Potentilla anserina* and *Cirsium arvense*. Prairie site 2 was enclosed by woodland and had such additional woodland species as *Rubus idaeus* and *Symphoricarpos occidentalis* and *Acer negundo* and *Quercus macrocarpa* seedlings. *Typha* site 1 was an area of open *Typha* marsh bounded on one side by a borrow pit and on the other by a mixed *Sonchus*-prairie community. Halophytic species, such as *Chenopodium rubrum*, *Atriplex patula* and *Scirpus paludosus*, and meadow species, such as *Melilotus alba*, *Hordeum jubatum*, *Trifolium repens* and *Potentilla anserina*, were present in addition to *Typha latifolia* and other marsh species, *e.g.*, *Eleocharis palustris*. *Typha* 2 consisted of a much more-closed *Typha* stand bordered by open areas colonized by annuals, by *Scolochloa* meadow and by *Scirpus* marsh. Only *Atriplex patula*, *Chenopodium rubrum*, *Rumex maritimus* and *Scolochloa festucacea* were found in any number within the *Typha* community.

Vegetation analysis of the present Delta Marsh communities and of the changes in vegetation since 1965 will help provide relevant information for marsh management schemes for wildlife and water regulation. It is to be hoped that the vegetation and soils of the transects and sites established during 1973 will continue to be monitored so that long-term changes in vegetation patterns can be assessed.

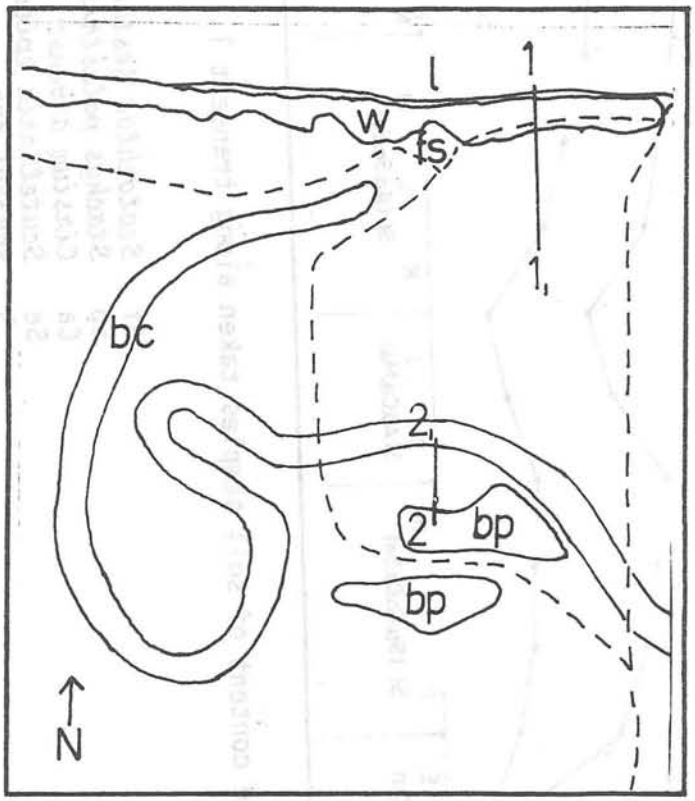


FIGURE 1. Sketch map to show positions of transects 1 and 2. (l = Lake Manitoba, w = woodland, fs = Field Station, bc = Blind Channel, bp = borrow pit, - - - = roads) Scale: 3 inches = 1 mile.

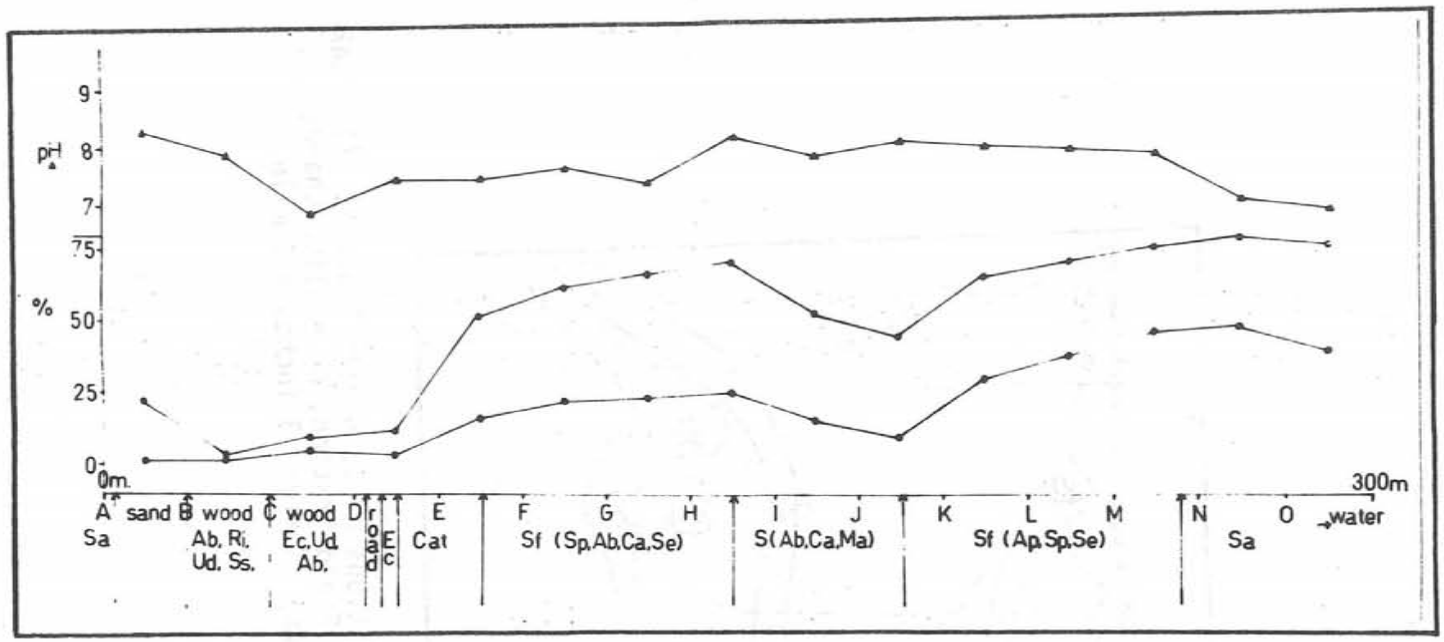


FIGURE 2. pH, organic and moisture content of soil samples taken along transect 1. (-▲- pH, -o- moisture content, -●- organic content)

Key: Sa	*Scirpus acutus*	Sf	*Scolochloa festucacea*
Ab	*Aster brachyactis*	Sp	*Stachys palustris*
Ri	*Rubus idaeus*	Ca	*Cirsium arvense*
Ud	*Urtica dioica*	Se	*Scutellaria epilobiifolia*
Ss	*Smilacina stellata*	S	*Sonchus* spp.
Ec	*Elymus canadensis*	Ma	*Mentha arvensis*
Cat	*Carex atherodes*	Ap	*Atriplex patula*

(Understorey species in parentheses)

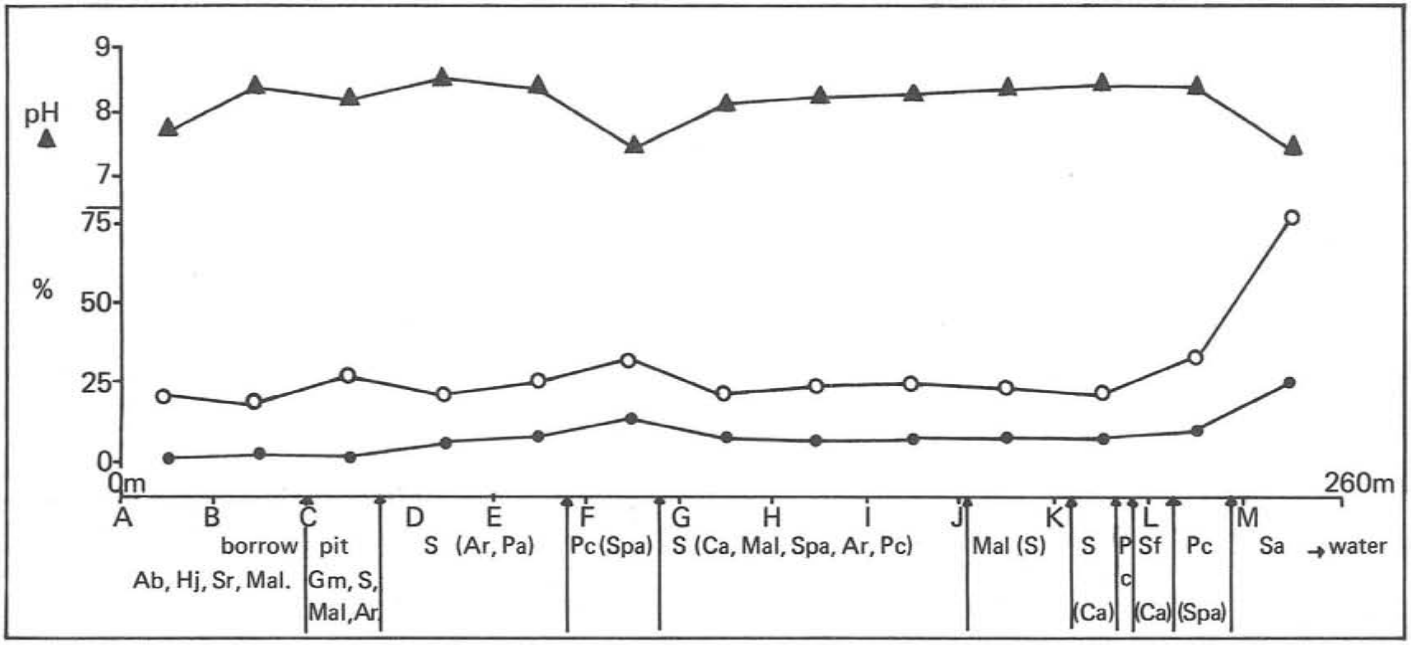
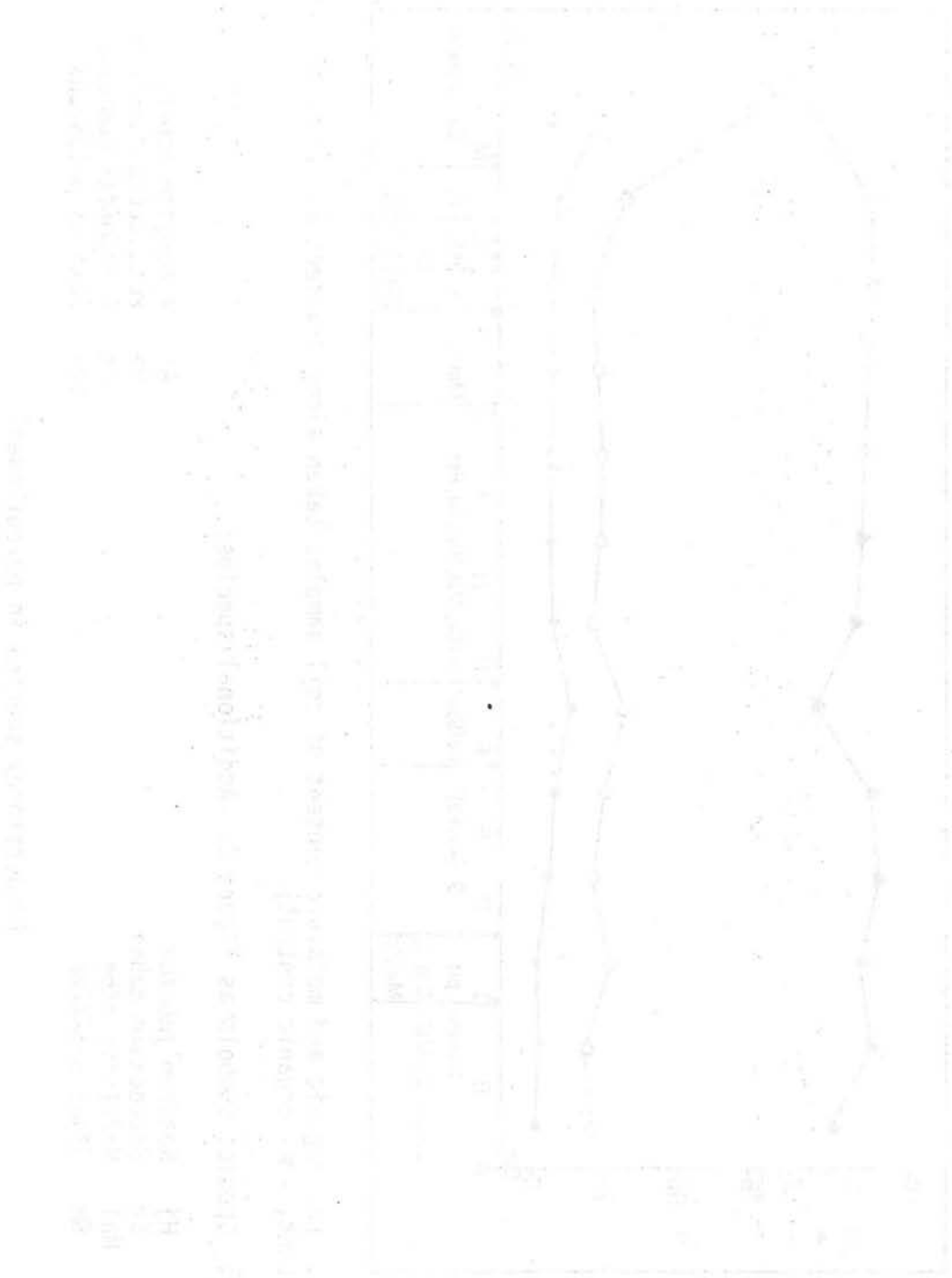


FIGURE 3. pH, organic and moisture content of soil samples taken along transect 2. (-▲- pH, -o- moisture content, -●- organic content)

Key: Species symbols as Figure 2. Additional species:

Hj	*Hordeum jubatum*	Ar	*Agropyron repens*
Sr	*Salicornia rubra*	Pa	*Potentilla anserina*
Mal	*Melilotus alba*	Pc	*Phragmites communis*
Gm	*Glaux maritima*	Spa	*Scirpus paludosus*

(Understorey species in parentheses)



The Effect of 2,4-Dichlorophenoxyacetic Acid upon Mixed Phytoplankton Populations in Southern Lake Manitoba and Delta Marsh

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Introduction

With more of our lakes, rivers and streams being polluted, water quality is becoming an important factor in our exsistence. Many chemicals and compounds, waste products of the home and industry, eventually enter our water systems, resulting in consequences unknown at present.

Much research must be undertaken to determine whether these consequences are beneficial or detrimental to life in the water and to mankind. This is a problem as there are many organisms in a body of water and probably many pollutants entering the system. One solution to this problem is to single out certain critical areas and study them. Such was the case at the University Field Station, Delta Marsh.

Lake Manitoba and Delta Marsh receive drainage from farmlands via tributaries such as the Assiniboine Diversion, the Blind Channel, Deep Creek and the Whitemud River. With greater demands of higher crops production, farmers are using more and more herbicides and pesticides which may enter the water system.

What effect do these chemicals have on the life in the marsh and the lake? Even this is too big a question to answer. Since algae are the primary producers in a body of water, that is the first trophic level in the food chain, a study was limited to the effect of some well-known herbicides 2,4-D, 2,4,5-T and pesticides D.D.T., abate and malathion upon existing mixed phytoplankton populations in Delta Marsh and southern Lake Manitoba. It was also hoped that algal assay organisms would be found for each of the above chemicals. So far 2,4-D has been the only chemical studied in depth. A number of different experiments were performed during the summer of 1973 and will be discussed in this paper.

Materials and Methods

Experimental work in the summer dealt with the effect of the herbicide 2,4-D upon mixed phytoplankton in the southern Lake Manitoba and

the Delta Marsh. The experiments may be classified into the following types:

1. 2,4-D enrichment, unlabelled
2. 2,4-D enrichment, labelled
3. 2,4-D enrichment, labelled and DNP
4. 2,4-D enrichment, labelled, light and dark
5. Respiration experiments
6. Arthur and Rigler, ^{14}C and labelled 2,4-D

Each of the above type of experiments was performed one or more times upon mixed phytoplankton from the marsh and lake. Dates, locations and types of experiments are listed in Table 1.

TABLE 1

Dates, Locations and Types of Experiments Performed upon Mixed Phytoplankton Populations in Southern Lake Manitoba and the Delta Marsh in the Summer of 1973

Date	Location	Type of Experiment
16 May	Marsh	2,4-D enrichment, unlabelled
17 May	Lake	2,4-D enrichment, unlabelled
18 May	Marsh	Arthur and Rigler (^{14}C)
21 May	Marsh	Arthur and Rigler (^{14}C)
25 May	Marsh	2,4-D enrichment, unlabelled
29 May	Lake	2,4-D enrichment, unlabelled
5 June	Marsh	2,4-D enrichment, labelled
7 June	Lake	Arthur and Rigler (^{14}C)
12 June	Marsh	Arthur and Rigler (2,4-D)
13 June	Marsh	2,4-D enrichment, labelled
25 June	Lake	2,4-D enrichment, labelled
25 June	Lake	Arthur and Rigler (2,4-D)
4 July	Marsh	2,4-D enrichment, labelled, light and dark
4 July	Marsh	Arthur and Rigler (2,4-D)
10 July	Marsh	Respiration experiment
11 July	Marsh	Respiration experiment
24 July	Lake	2,4-D enrichment, labelled, light and dark
28 July	Lake	2,4-D enrichment, labelled and DNP
7 August	Marsh	2,4-D enrichment, labelled and DNP
8 August	Marsh	Arthur and Rigler (^{14}C and 2,4-D)
10 August	Marsh	Respiration experiment

Field Procedure

Single stations in the marsh and the lake were subjectively selected. Water[1] collection from both stations followed the same procedure for all experiments. A Van-Dorn type sampler was used to collect water from depths 0 and 2 m in the marsh and the lake respectively. Large zooplankters were removed from the water by filtering through a 106-μ mesh net and water was transported back to the lab in darkened 2-liter carboys. Enough water was taken back for experimental work, pH and alkalinity determinations. Temperature readings were also taken at each station at time of experimentation.

Laboratory Procedure

Water samples were shaken to ensure an homogeneous suspension of phytoplankton. The samples were divided into aliquots, the volumes dependent on the type of experiment. Replicates of three were employed with each addition of labelled 2,4-D in each experiment.

Stock solutions of labelled sodium bicarbonate (^{14}C) and 2,4-D labelled and unlabelled were prepared so that additions of these compounds were known in terms of μg C/l. Additions of the stock solutions were performed with either micropipets or sterile 1-ml syringes.

The samples were incubated in a growth chamber for a period of four hours at a temperature comparable to that of the natural environment. Illumination was provided by Cool White General Electric fluorescent fixtures at approximately 260 foot candles.

At the duration of four hours, samples were filtered through 0.45-μ Sartorius membrane filters. The filters were then either washed with 10 ml distilled water and fumed over HCl[2] for one minute or just washed with 50 ml of distilled water, the former for experiments with ^{14}C and the latter for 2,4-D. Vacuum pressure while filtering was not monitored but was consistent for all experimental work. The filters, still damp, were placed in scintillation vials containing 10 ml of scintillation fluor (either Bray's fluor or Aquasol-New England Nuclear).

Scintillation counting was performed in a Picker Liquimat 2000. Counting period for each vial was 10 or 20 minutes with the built-in statistic set at 1.5±2.0 standard deviations. Counts were converted to disintegrations per minute as outlined in the Channels Ratio Method (Wang and Willis, 1965) and values were recorded and analyzed on the basis of mean values of triplicate flasks.

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[1]Water refers to mixed phytoplankton and bacteria.

[2]Fuming over HCl drives off any inorganic carbon on the surface of the cells or filter paper.

A Radiometer pH meter, Model 29 was used for the pH readings, whereas determinations of alkalinity were done chemically, procedures of APHA (1971).

2,4-D Enrichment Experiments, Unlabelled

Forty-two 60-ml glass BOD bottles were utilized in an experiment. Stock solutions of 2,4-D were prepared so that final concentrations per 60 ml were equivalent to 50 to 5,000 µg C/l (Table 2).

TABLE 2

2,4-D Enrichment, Unlabelled

Sample Number[1]	2,4-D Enrichment (µg C/l)
1	0
2	15
3	25
4	35
5	50
6	150
7	250
8	350
9	500
10	1,500
11	2,500
12	3,500
13	5,000

[1]Each sample number refers to triplicate experimental flasks.

Phytoplankton responses of 2,4-D enrichment were monitored with uptake of ^{14}C, 2 µci administered to each experimental flask. Incubation and light intensity were as stated in the previous section.

In experiment #1, the marsh, the whole 60-ml sample was filtered. This was changed to 30 ml in subsequent experiments to prevent clogging of the filters. A 10-ml wash followed filtration of samples and the filter was then fumed over HCl for one minute. Two experiments of this type were performed on the marsh and the lake.

2,4-D Enrichment Experiments, Labelled

For this and the rest of the experiments, 21-ml sample bottles were used as experimental flasks; 25-ml aliquots of mixed phytoplankton were placed in each bottle. Labelled 2,4-D in concentrations varying from 10.5 to 1,052 µg C/l were pipeted in allocated flasks (Table 3). The rest of the procedures were the same as above, except that instead of fuming, filters were washed with 50 ml of distilled water.

TABLE 3

2,4-D Enrichment, Labelled

Sample Number[1]	2,4-D Enrichment (µg C/l)
1	10.5
2	31.6
3	52.6
4	73.6
5	105.2
6	315.6
7	526.0
8	736.4
9	1,052.0

[1]Each sample number refers to the triplicate experimental flasks and one control flask.

2,4-D Enrichment Experiments and Dinitrophenol

The result of uptake of labelled 2,4-D appears to be that of passive diffusion. In order to substantiate or repudiate this statement, two experiments with 2,4-D and DNP were performed. The experiments consisted of two series of experimental flasks. The first series was identical to the typical uptake experiment with labelled 2,4-D. The second series was a repeat of the first but with the addition of DNP in the concentration of 10^{-4} Molar.

2,4-D Enrichment Experiments, Light and Dark

When dealing with natural phytoplankton, bacteria are also present. The effect of their presence must be differentiated from that of algae. One way of doing this is with light and dark bottles. An experiment again consists of two series of experimental flasks. Procedures for both

series of flasks were the same as the typical uptake experiment for labelled 2,4-D except that one series was comprised of dark bottles.

Respiration Experiments

These were designed to demonstrate that, once labelled 2,4-D had been taken up, it was respired or it became a cellular component. An experiment consisted of eight 25-ml bottles, into which 20 ml of mixed phytoplankton were placed. Approximately 1.0 µci of labelled 2,4-D was put in each experimental flask. Four of the eight bottles were capped normally (manufacturer's top) while serum stoppers were put in the others. The serum stoppers had a syringe needle passing through them to which tubing and a clamp had been attached. After a four-hour incubation period, the bottles with the manufacturer's tops were filtered in the normal way. The other bottles with the serum caps were acidified then degased into phenethylamine for 30 minutes. Three 1-ml aliquots of phenethylamine were put into aquasol, then counted. The samples were then filtered and washed as usual.

Arthur and Rigler Experiments

Thus stated so far, all experimentation was comprised of the uptake of 2,4-D. This next set of experiments, termed Arthur and Rigler, are dealing with the filtering of the algal samples. Arthur and Rigler (1967) and others have noted that the activity of plankton decreases with the increase in volume filtered. Others state that this is not the reason, but it is due to self-absorption of the filter papers. To solve this problem, a number of experiments were performed throughout the course of the summer (Table 1).

Mixed phytoplankton samples from either the marsh or the lake were divided into six 60-ml BOD bottles. Approximately 2 µci of ^{14}C or labelled 2,4-D were added to each bottle. At the termination of four hours incubation, the contents of the bottles were mixed together. Triplicate volumes of 1, 2, 3, 5, 7, 10, 15 and 25 ml were filtered through separate 0.45-µ membrane filters. Procedure then followed prestated procedures.

Results

2,4-D Enrichment Experiments, Unlabelled

Two experiments were performed on the marsh and on the lake. Experimental results in all four cases show similar trends (Figs. 1 and 2). Higher uptake of ^{14}C is observed with 2,4-D additions in the range of 15 to 500 µg C/l as compared with 500 to 5,000 µg C/l.

2,4-D Enrichment Experiments, Labelled

Four enrichment experiments with labelled 2,4-D were performed upon

mixed phytoplankton on the marsh and four upon the lake. Similar responses occurred in all experiments, but the trends observed differed greatly from the responses noted with unlabelled 2,4-D. In this set of experiments, mixed phytoplankton uptake of 2,4-D appeared to be in direct proportion to the concentration added (Figs. 3 and 4). Further evidence for this are linear regression correlation coefficients, which range from 0.948 to 0.997.

2,4-D Enrichment Experiments and Dinitrophenol

The responses of marsh and lake phytoplankton differed in these experiments (Figs. 5 and 6). Although uptakes of 2,4-D and DNP are linearly related to the concentration added, the slope of the uptake line for the marsh changes markedly with the addition of 2,4-D and DNP. This response is not noted in the lake.

2,4-D Enrichment Experiments, Light and Dark

The results of these experiments are presented in Figs. 7 and 8. Uptake of 2,4-D by marsh and lake phytoplankton is much less than that of uptake in the light.

Respiration Experiments

A peculiar response is noted in the three experiments. The acidified samples show greater uptake of 2,4-D compared to that of the normal samples even after being degased for 30 minutes. Further experimentation is needed to determine the reason.

Arthur and Rigler Experiments

The results are presented in Table 4. A decrease in the activity of plankton with increase in volume filtered is noted in some experiments while in others it is absent. This phenomenon occurs more frequently when dealing with 2,4-D as compared to ^{14}C.

Discussion

The stimulatory and inhibitory responses, expressed as uptake of ^{14}C of marsh and lake phytoplankton (Figs. 1 and 2) with low (15-500 µg C/l) and high (500-5,000 µg C/l) concentrations of unlabelled 2,4-D respectively, are not explainable at present. It is suspected that in some way 2,4-D at high concentrations inhibits or blocks the mechanism of ^{14}C uptake. Uptake of labelled 2,4-D by mixed phytoplankton populations of the marsh and the lake show a linear relationship in that uptake expressed in disintegrations per minute is directly proportional to the amount of 2,4-D added to experimental flasks. Linear regression correlation co-

TABLE 4

Arthur and Rigler Experiments

Sample Number	Volume Filtered (ml)	Marsh, 18 May, ^{14}C	Marsh, 12 June, 2,4-D	Marsh, 4 July, 2,4-D	Marsh, 8 August, ^{14}C	Marsh, 8 August, 2,4-D	Lake, 7 June, ^{14}C	Lake, 25 June, 2,4-D
		Mean Value (DPM/ml Filtered)						
1	1.0	42	62	86	454	46	131	68
2	2.0	37	68	63	419	27	80	55
3	3.0	37	58	51	452	21	66	30
4	5.0	33	48	46	454	30	42	38
5	7.0	39	47	43	328	20	45	30
6	10.0	39	44	34	431	18	36	26
7	15.0	43	38	34	426	18	34	48
8	25.0	43	40	40	434	19	36	42

efficients from 0.948 to 0.997 further substantiate this. This response, noted four times in the marsh and four times in the lake, indicates passive diffusion by algae, bacteria or both.

Passive diffusion may be defined as a process by which a difference in solute concentrations interior and exterior to a cell are equilibriated without the expenditure of energy. With reference to our experiments, the solute is 2,4-D and the difference in solute concentrations is the amount of 2,4-D added to experimental flasks.

Experiments with mixed phytoplankton and labelled 2,4-D and dinitrophenol give partial support to the above statements.

Dinitrophenol (DNP), an uncoupling agent, prevents oxidate phosplorylation and therefore energy production of a cell. If uptake of 2,4-D is not passive diffusion, then the alternative is active uptake. This mechanism requires energy and consequently will come to a halt in the presence of DNP. No appreciable change in uptake by phytoplankton with the addition of labelled 2,4-D and labelled 2,4-D and DNP is noted in the lake (Fig. 6). However, this response is quite different in the marsh (Fig. 5). Although a linear relationship exists in the control samples without DNP and the experimental samples with DNP, a marked dif-

ference is noted in the uptake by phytoplankton in both series of flasks. In comparing the slopes of the two lines, phytoplankton uptake of 2,4-D in the presence of DNP is approximately one-third of the phytoplankton uptake of 2,4-D alone, 0.55 and 1.62 respectively. The response differences of phytoplankton in the lake and marsh may be explained in algal and bacterial composition in each. Quite possibly there is a different effect of DNP upon algae and bacteria and consequently different proportions in the lake and the marsh at the time of experimentation could change the results.

Uptake by lake and marsh phytoplankton is found to be less in the dark as compared to the light (Figs. 7 and 8). Slope of the lines for the dark experiments of the marsh and the lake is 0.95 and 1.49 respectively as opposed to 1.42 and 2.05 respectively in the light. It is also noted that uptake of labelled 2,4-D in the dark by marsh phytoplankton is higher initially at lower additions of 2,4-D than that of the light. This indicates that both algae and bacteria play a vital role in the uptake of 2,4-D.

If a decrease in the activity of plankton with increase in volume filtered is noticed, experimental results have to be adjusted for this. This phenomena is noted in some experiments while absent in others. Some workers, Arthur and Rigler (1967) and Kuenzler and Ketchum (1962), state that this is a filtration phenomena while others believe it is due to self-absorption of the filter papers. Experimental results from the summer appear to support the latter.

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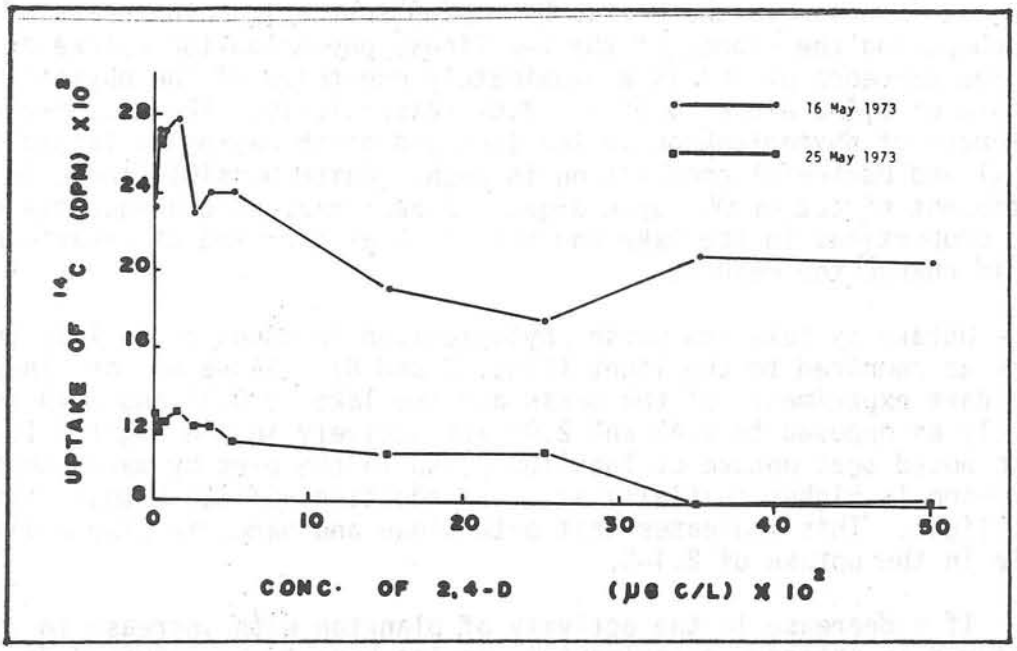


FIGURE 1. The Relationship between Mixed Phytoplankton Uptake of Uniformly Labelled ^{14}C and Varying Concentrations of 2,4-D in Delta Marsh.

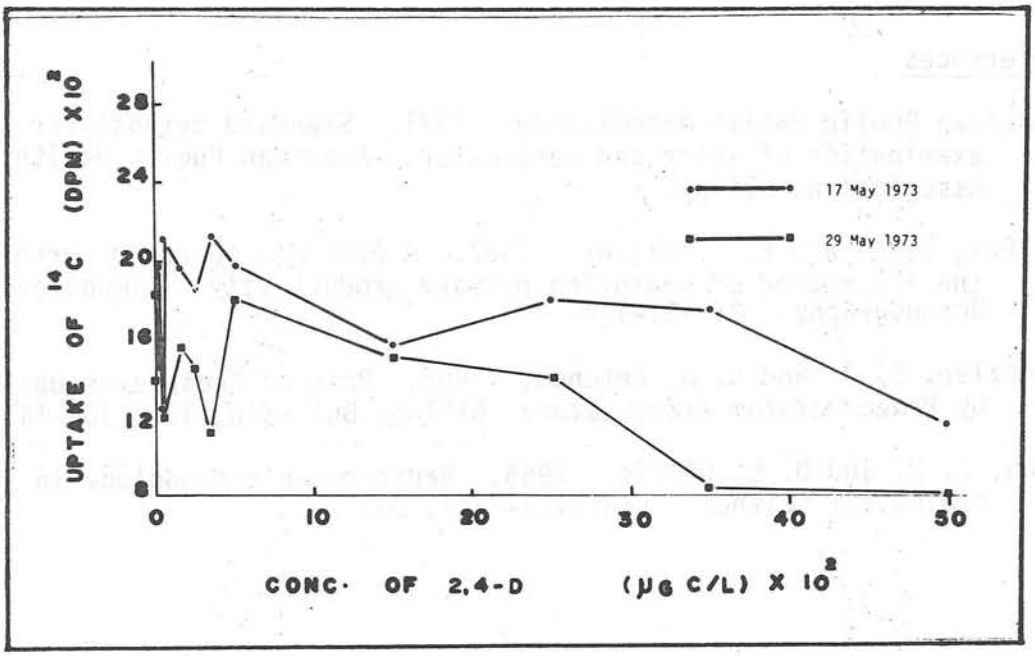


FIGURE 2. The Relationship between Mixed Phytoplankton Uptake of Uniformly Labelled ^{14}C and Varying Concentrations of 2,4-D in Southern Lake Manitoba.

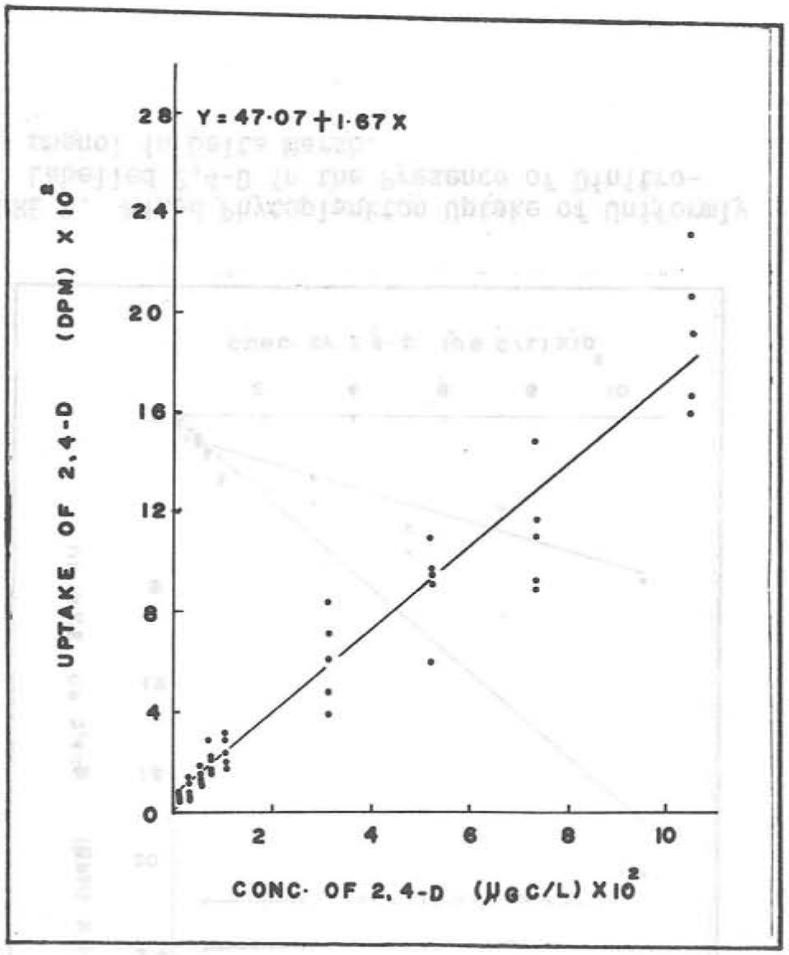


FIGURE 3. Mixed Phytoplankton Uptake of Uniformly Labelled 2,4-D in Delta Marsh.

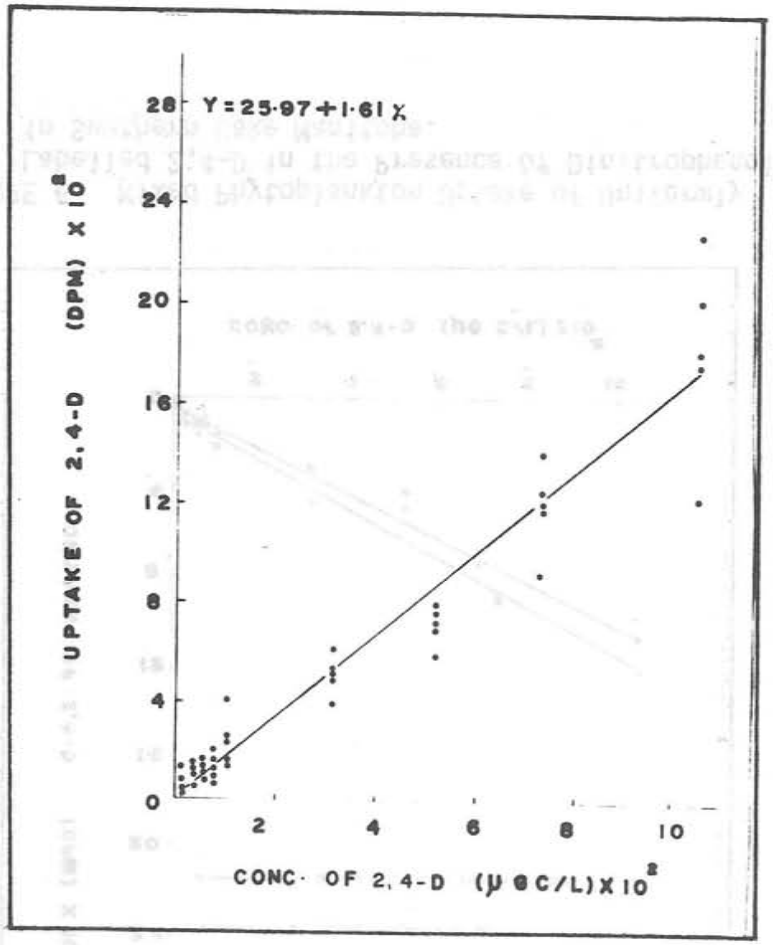


FIGURE 4. Mixed Phytoplankton Uptake of Uniformly Labelled 2,4-D in Southern Lake Manitoba.

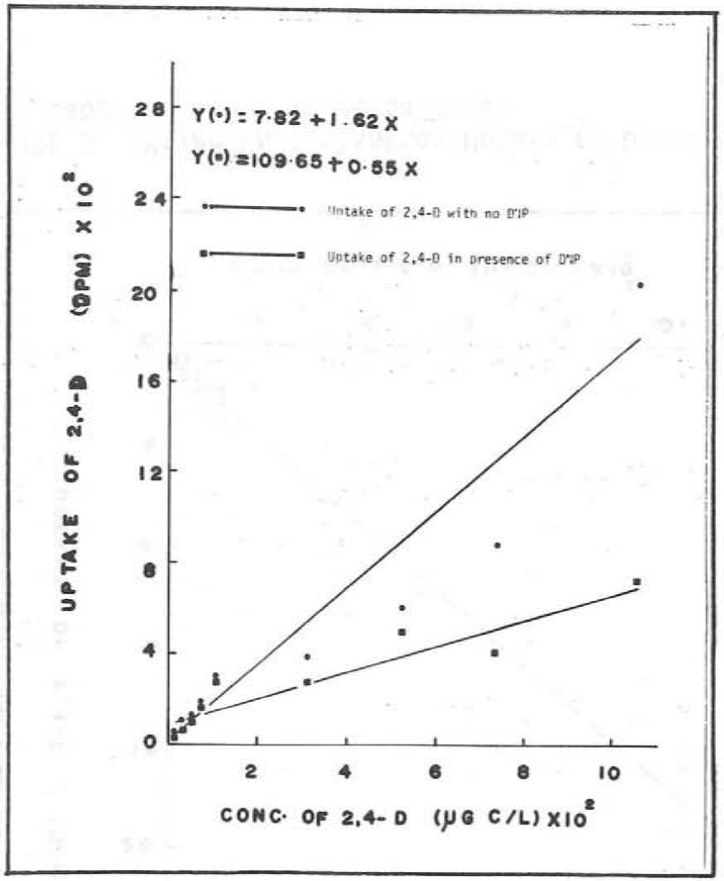


FIGURE 5. Mixed Phytoplankton Uptake of Uniformly Labelled 2,4-D in the Presence of Dinitrophenol in Delta Marsh.

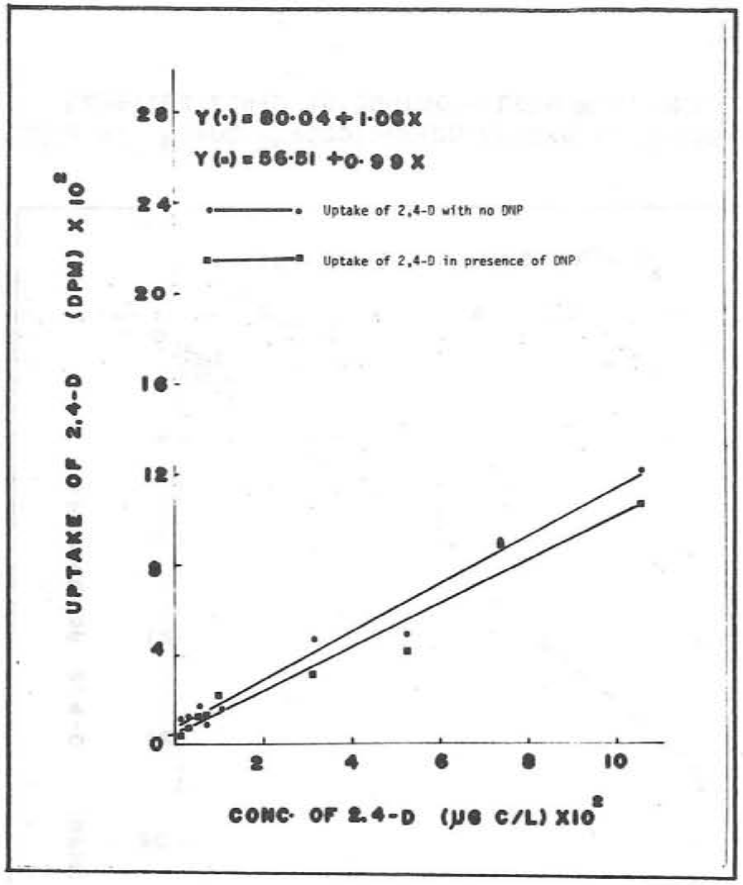


FIGURE 6. Mixed Phytoplankton Uptake of Uniformly Labelled 2,4-D in the Presence of Dinitrophenol in Southern Lake Manitoba.

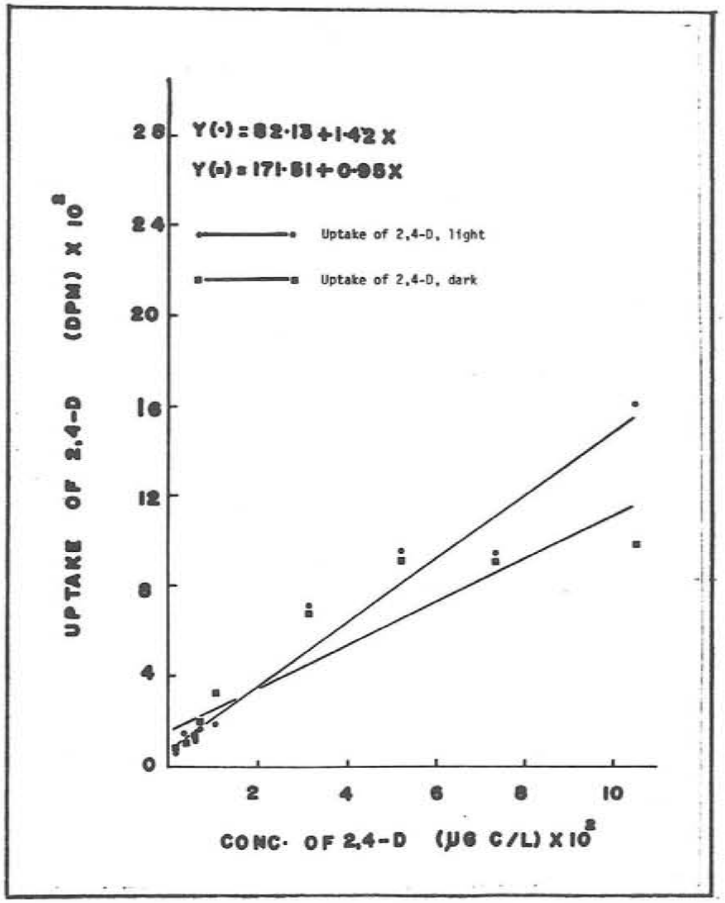


FIGURE 7. The Relationship between Mixed Phytoplankton Uptake of Uniformly Labelled 2,4-D in the Light and in the Dark in Delta Marsh.

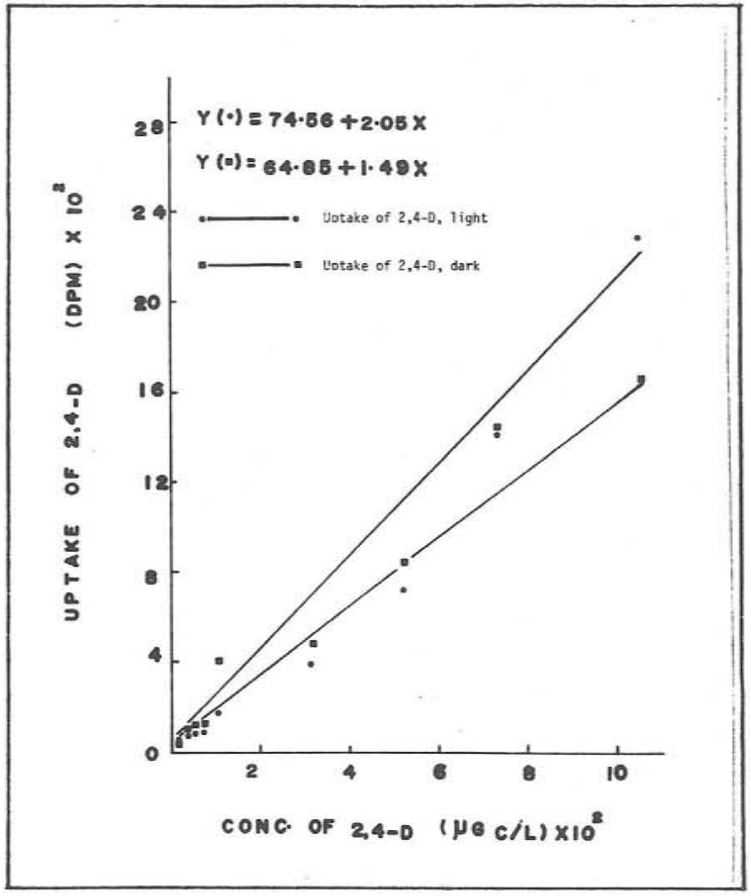
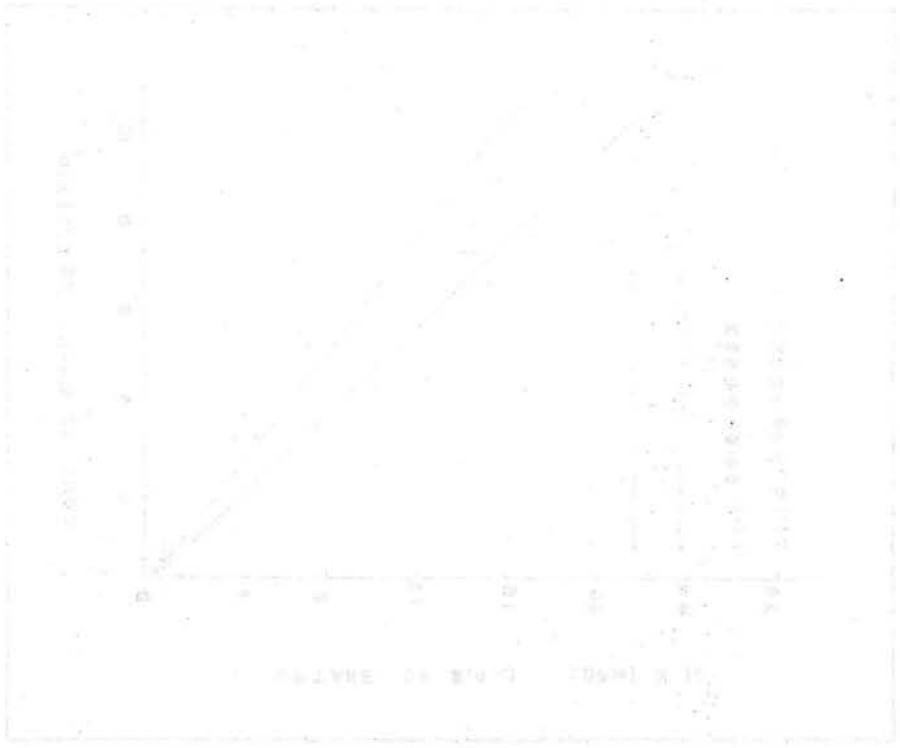
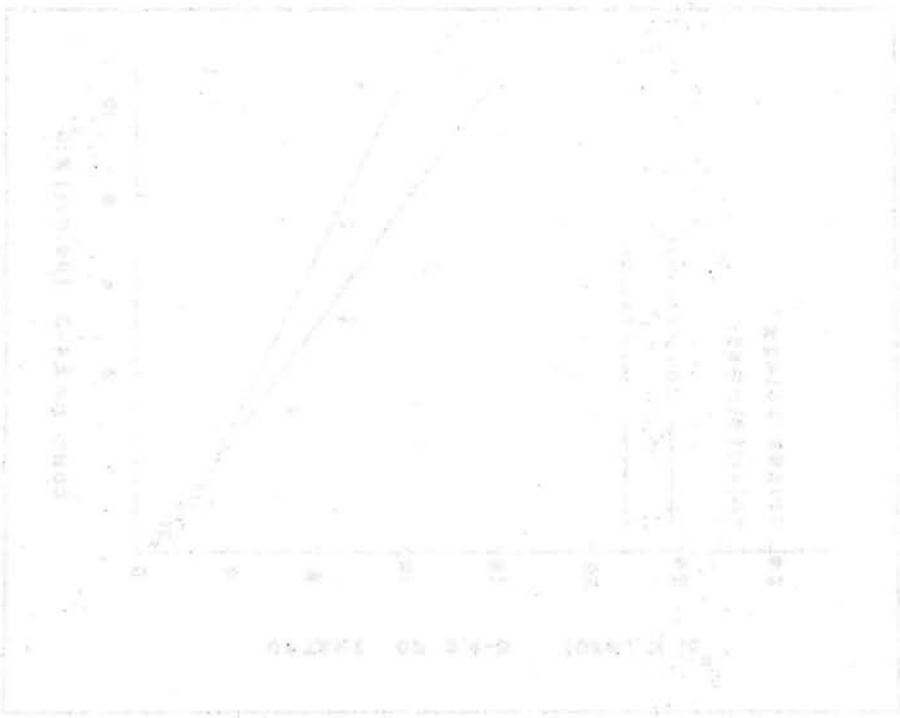


FIGURE 8. The Relationship between Mixed Phytoplankton Uptake of Uniformly Labelled 2,4-D in the Light and in the Dark in Southern Lake Manitoba.





Measurement of the Primary Production of Epiphytic Algae on Macrophytes

N. Hooper

Department of Botany

Introduction

A study was conducted from May to October 1973 at Delta Marsh to examine the use of natural and artificial substrates in the assessment of epiphytic algal production. This report presents some preliminary results.

The natural substrates were the macrophytes *Phragmites communis*, *Myriophyllum* sp., *Typha latifolia*, and *Scirpus validus*. Artificial substrates of glass and acetate were positioned at a number of sites predominated by individual species of these macrophytes. Emphasis was placed on the use of the acetate substrate. Throughout the season determinations were made of ^{14}C uptake ($\mu g/cm^2/4$ hr. incubation time) and biomass accumulation, and material was collected for taxonomic examination. Preliminary experiments on rates of epiphytic attachment and detachment were also conducted.

Methods

The apparatus used in securing the artificial substrates is shown in Fig. 1. The acetate strips were 6 x 50 cm. The glass slides, measuring 2.5 x 7.0 cm, were cemented into rubber stoppers and the stoppers were suspended from a crossbar in the centre of the frame. The frames were placed at each of the macrophyte stands of *Phragmites communis*, *Typha latifolia*, *Scirpus validus*, and *Myriophyllum* sp. Each of these sites in the Blind Channel was sampled at two-week intervals throughout the sampling period.

In the regular sampling procedure, a number of 3-cm^2 samples were cut from the acetate and plant substrates. Each section was placed in a dark glass jar. These jars had been prepared prior to sampling with 15 ml filtered (0.45-μ membrane filter) marsh water for samples used for C uptake determination or 15 ml distilled water for samples used for C and N analysis. The glass substrate was sampled by placing a glass slide in a large black jar containing 20 ml filtered marsh water. In addition, samples of epiphytes on each substrate were secured for taxonomic examination.

For C uptake determination, half the acetate samples were measured and placed in 30-ml capacity BOD-type incubation bottles. The original 15 ml plus an additional 10 ml of filtered marsh water were added. The rest of the acetate samples and the plant samples were scraped with a razor to remove the epiphytes. The scraped material was placed in incubation bottles. Substrate areas were measured directly except in the case of *Myriophyllum*, where plant material was dried and the dry weight converted to surface area. A conversion factor of 3.0 mg/cm^2 had been determined.

Each glass slide was scraped and the total scraped area determined. The scraped material was made up to known volume with additional filtered marsh water. A volume of material representing a surface area of 3 cm^2 was pipetted into each incubation bottle. The total volume in each bottle was made up to 25 ml.

To each incubation bottle 0.5 ml of ^{14}C-labelled sodium bicarbonate (1.4 µci/ml) was added and mixed by shaking. Samples were incubated at 15^{0}C and 260 foot-candles for four hours. Each sample was then filtered through a 0.45-µ Sartorius membrane filter and rinsed with 10 ml distilled water. The filters were then fumed over concentrated HCl for one minute to remove any inorganic C. Samples containing unscraped acetate were filtered, then the filter and the acetate fumed together. These samples were then placed in 10 ml Bray's scintillation fluor. Other filters were placed in either Bray's fluor or Aquasol. Bray's fluor was used for the acetate samples as the acetate was soluble in this fluor. Radioactivity was determined in a scintillation counter (Picker Nuclear Liquimat 220). All counts were made to a preset statistic of 1.5±2σ. Counting efficiency was determined by the channels ratio method (Wang and Willis, 1965).

The rate of C uptake in µg C/cm^2/4 hr. incubation period was calculated by the equation:

$$\underset{\text{incubation}}{\mu g\ C/cm^2/4\ hr.} = \frac{\text{activity in sample}}{\text{activity added}} \times \frac{\text{dissolved inorganic C}}{\text{area sampled}} \times 1.05$$

The value 1.05 is a correction factor for isotope discrimination.

Samples for C and N determination were filtered onto precombusted glass fiber filters. The filters were stored in a dessicator until determinations were made with a Perkin Elmer CHN analyzer.

An experiment was designed to estimate rates of epiphytic attachment and detachment to and from the acetate strips. These were to be measured in terms of C uptake and C and N weights according to the procedures already described. A previously exposed strip was sampled to determine the initial epiphyte colonization. The strip was split longitudinally. One-half was left exposed and the other half was suspended in a clear Plexiglass tube (diameter of 2.5 cm). This tube was sealed at the bottom and filled to the water level with filtered marsh water. This tube was replaced in the channel and epiphytes detaching from the acetate strip were contained within the tube. A new acetate strip was exposed at the site to measure attachment. After a set time

interval, the acetate strips were sampled. The total area of the acetate strip in the Plexiglass tube was determined as well as the volume of the water within it. The detached epiphytes in the water were sampled and, by determining the volume to area relationship of the water and the substrate, the detachment per cm^2 was estimated.

Results and Discussion

The results of the C uptake determinations of the epiphytes for the season are given in Figs. 2-5. The C uptake technique was used as a relative measurement of epiphytic colonization. Samples were incubated under constant growth chamber conditions and hence do not reflect *in situ* values.

In the *Phragmites communis* stand (Fig. 2), the epiphytic growth on the macrophyte lagged behind the acetate and glass substrates until early July. Between July 1 and July 19 there was a great increase in C uptake on all substrates. After this date the plant and acetate substrates give similar values for C uptake until mid-October. Evaluation of the glass slides was difficult because few escaped breakage during the season. One explanation for the spring discrepancy between the natural and artificial substrates may be that the natural substrate has been exposed for colonization for a shorter period of time. This could have been due to the appearance of new shoots or to an increase in the surface area of the shoots due to growth. While C uptake on the acetate substrate increases in mid-October, it decreases on the natural substrate. The autumn condition of the macrophyte may be exerting some effect on the epiphytes.

The epiphytes on *Scirpus* had a seasonal lower rate of C uptake than the epiphytes on the artificial substrates (Fig. 3). The same general seasonal trend occurs on all substrates, however, with a maximum value in late July. The discrepancies between the macrophyte and the artificial substrates may have been due to non-identical placement of the substrates for epiphytic growth. The artificial substrates were positioned in slightly deeper water and were slightly less shaded. This would not likely account for such a vast difference. It may be that *Scirpus validus* in some way exerts an influence on epiphytic colonization.

At the *Typha* site the C uptake values were low (<10 μg $C/cm^2/4$ hr. incubation) for all substrates until late August (Fig. 4). This decreased colonization was caused by a thick mass of decaying plant material which was blown to the site. The mass, comprised largely of uprooted *Myriophyllum*, originated when spawning carp stirred up the area and was compounded by strong winds. The mass may have decreased epiphytic colonization because of a scraping effect on the substrates, some chemical alteration in the stagnant water or reduced light penetration. Sampling of the *Typha* plants in a non-affected area showed an uptake of 24.25 μg $C/cm^2/4$ hrs. compared with a mean of 0.90 μg $C/cm^2/4$ hrs. for the affected substrate in late July. Carbon uptake greatly increased in September on all substrates when the mat had decayed and dispersed. The drastic drop in uptake on the natural surface between September 29 and October 14 cor-

responds to the browning of the *Typha* leaves.

The overall C uptake values for all substrates were greatest at the *Myriophyllum* site (Fig. 5). The epiphytes on the acetate reached a maximum in July. The epiphytes on the plant substrate increased slowly at first and reached a maximum in late September. The acetate values were probably higher in early summer because of the great growh of *Myriophyllum* occurring during this period. Therefore the plant exposure time for colonization may have been less. Also the partially horizontal surface of the *Myriophyllum* varied from the completely vertical surface of the acetate. Preliminary results do suggest that *Myriophyllum* may be a substrate of major significance for epiphytic growth.

It was felt that, if acetate provides a reliable substrate for colonization, there are several advantages to warrant its use. The breakage problem occurring with glass slides is eliminated. The material is flexible, so the substrate surface could be arranged in a number of ways. The acetate can be cut in the field, so *in situ* incubation with good replicates is possible. Finally, for C uptake determinations, the need for scraping is eliminated because the acetate is soluble in Bray's fluor. A comparison of scraped and non-scraped replicate samples (Fig. 6) shows the error introduced by scraping. Scraping may decrease uptake by 45% or increase it by as much as 178%. Decreases may be due to incomplete scraping or damage to cells. Increased uptake may be due to reduced clumping of cells. Therefore the elimination of scraping greatly increases the reliability of results.

The results of an experiment to measure attachment and detachment are given in Fig. 7. The change in the uptake of the initial strip during the seven days in August was an increase of 18%. Of this increase, approximately 45% was due to attachment and growth of new epiphytes and 55% to growth of the original epiphytes. Approximately 1% of the epiphytic material became detached from the original strip in seven days. These results are verified by adding the attachment value to the enclosed column strip value. This sum approximates the exposed strip value as would be expected.

As was stated, this report presents only preliminary results. Most C-N determinations and all taxonomic examinations remain to be done. The further use of acetate as an artificial substrate does seem warranted. Closer attention should be paid to the increase in surface area of natural substrates due to growth in early summer so that samples of equal exposure times can be obtained. Possible future prospects include *in situ* measurements of C uptake to assess productivity, heterotrophic uptake of organic acids, and analysis of macrophyte-epiphyte interactions.

References

Wang, C. H. and D. L. Willis. 1965. Radiotracer methodology in biological science. Prentice-Hall, 366 pp.

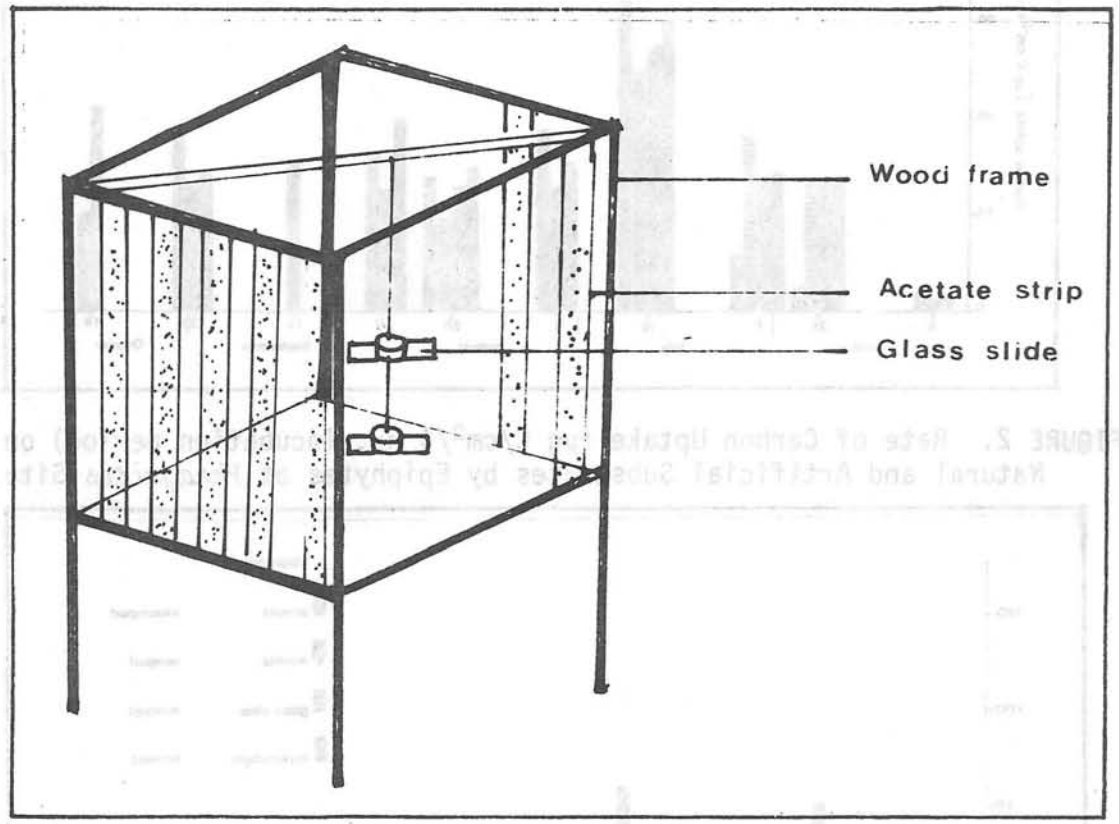


FIGURE 1. Arrangement of Artificial Substrates for Epiphytic Attachment.

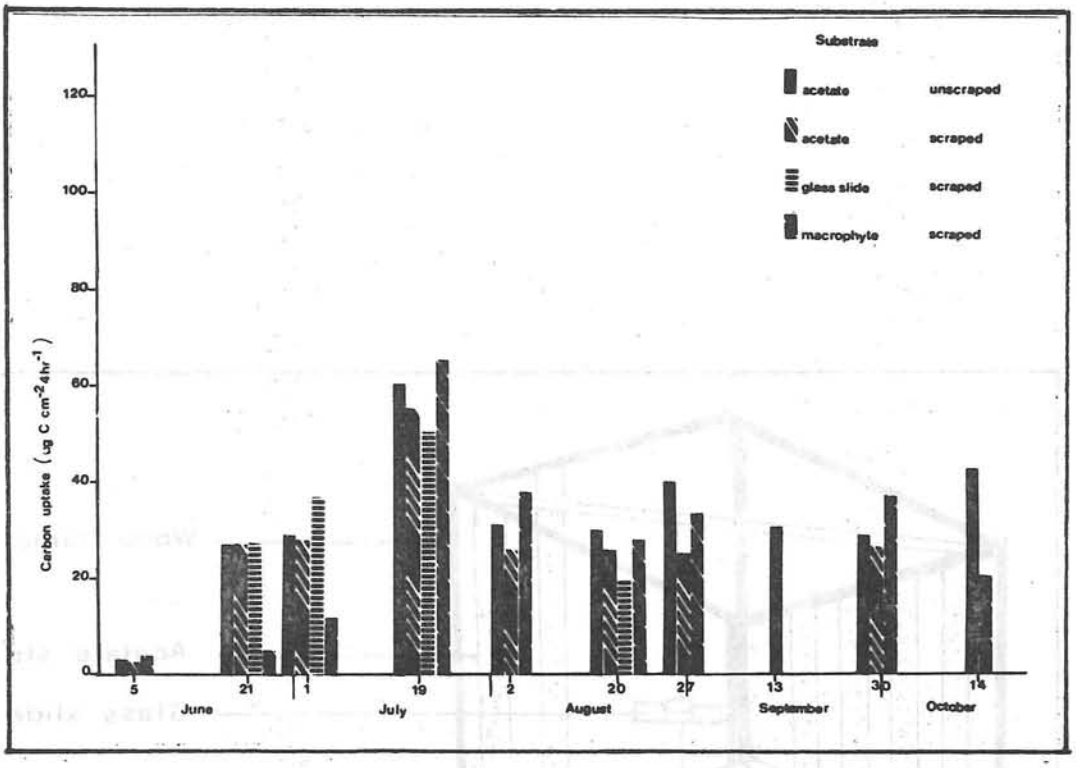


FIGURE 2. Rate of Carbon Uptake (μg C/cm^2/4 hr. incubation period) on Natural and Artificial Substrates by Epiphytes at *Phragmites* Site.

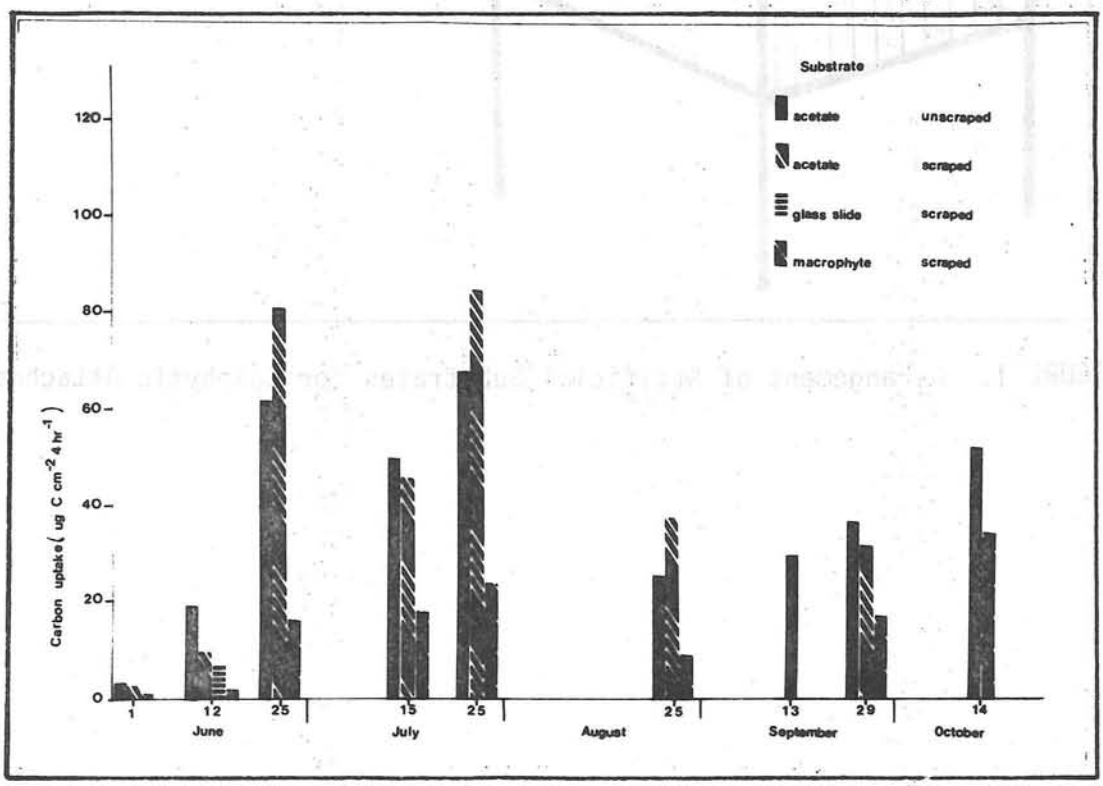


FIGURE 3. Rate of Carbon Uptake (μg C/cm^2/4 hr. incubation period) on Natural and Artifical Substrates by Epiphytes at *Scirpus* Site.

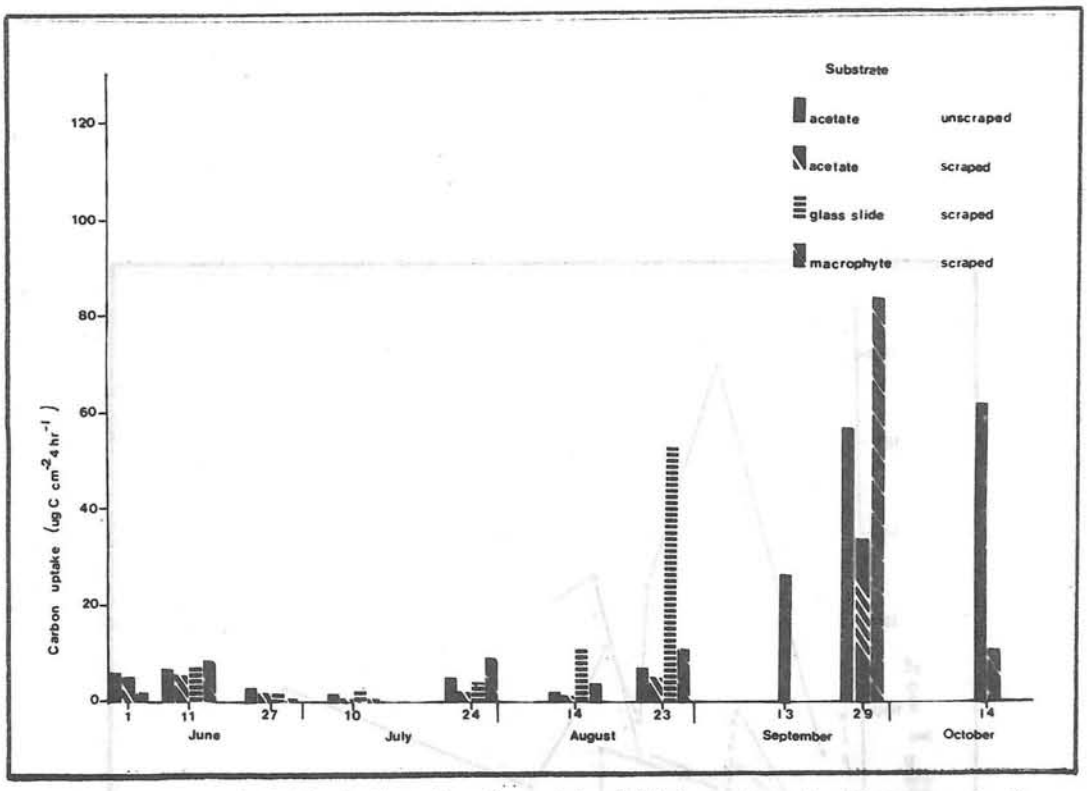


FIGURE 4. Rate of Carbon Uptake (µg C/cm^2/4 hr. incubation period) on Natural and Artificial Substrates by Epiphytes at *Typha* Site.

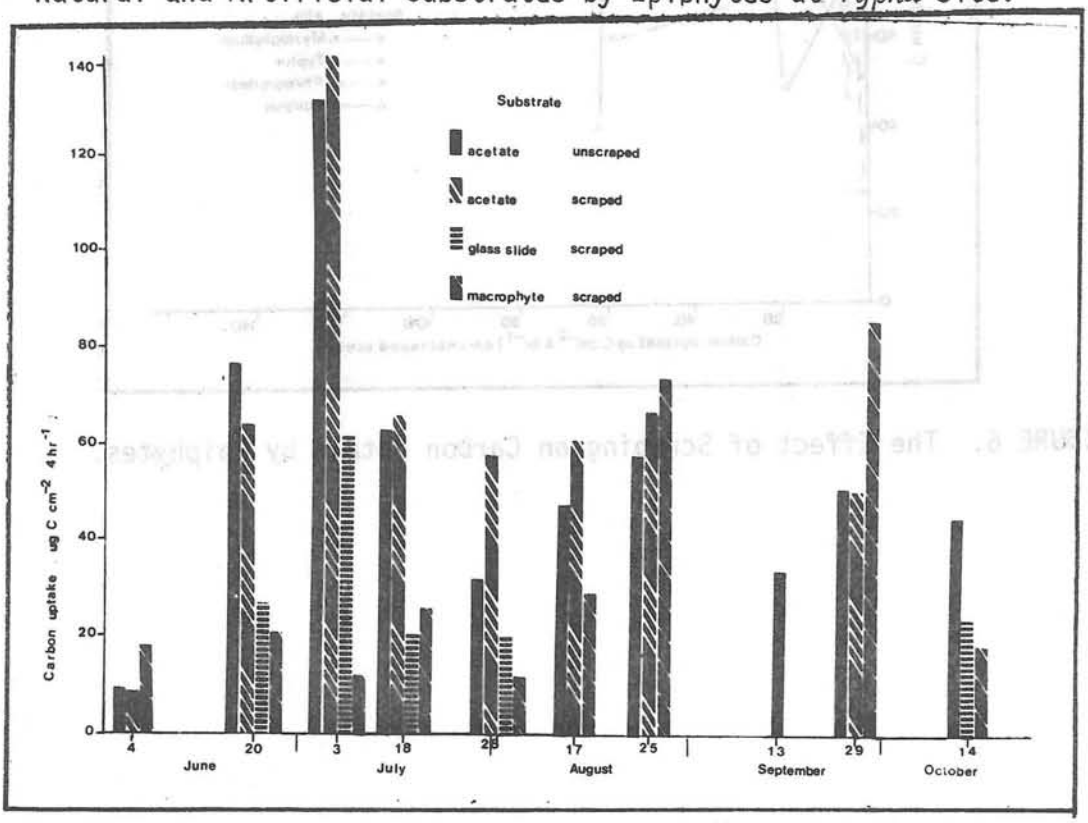


FIGURE 5. Rate of Carbon Uptake (µg C/cm^2/4 hr. incubation period) on Natural and Artificial Substrates by Epiphytes at *Myriophyllum* Site.

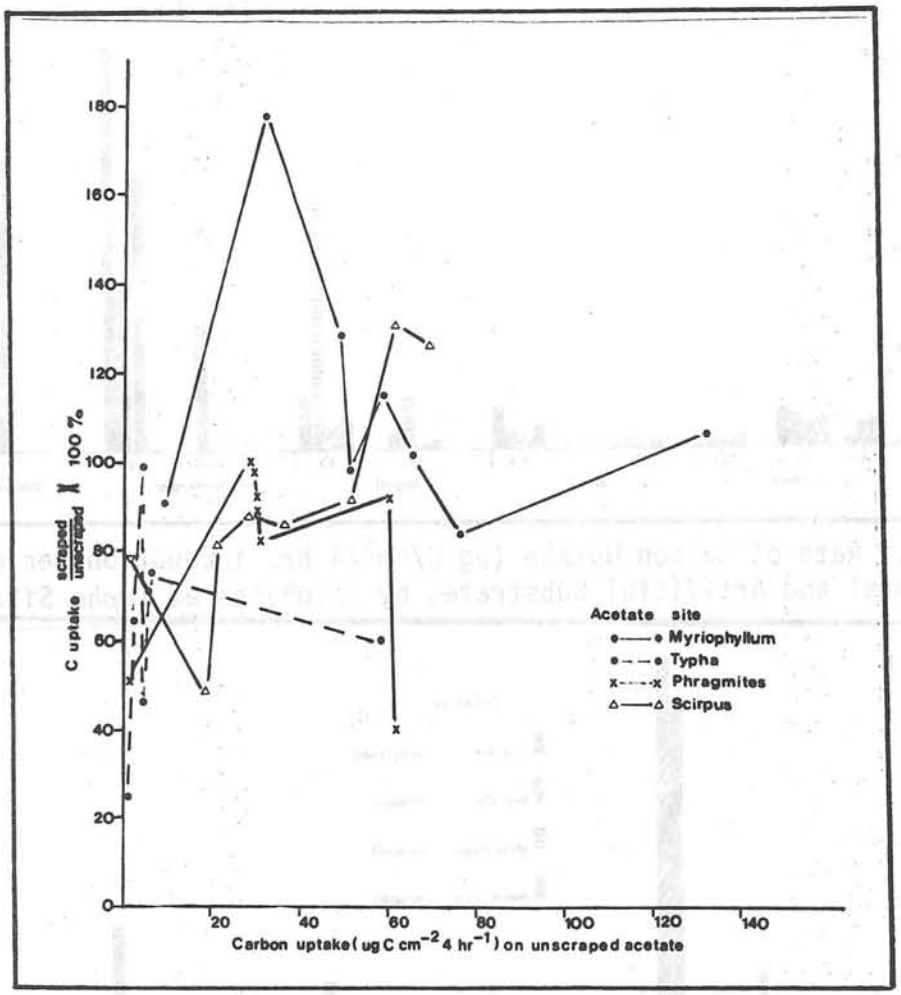


FIGURE 6. The Effect of Scraping on Carbon Uptake by Epiphytes.

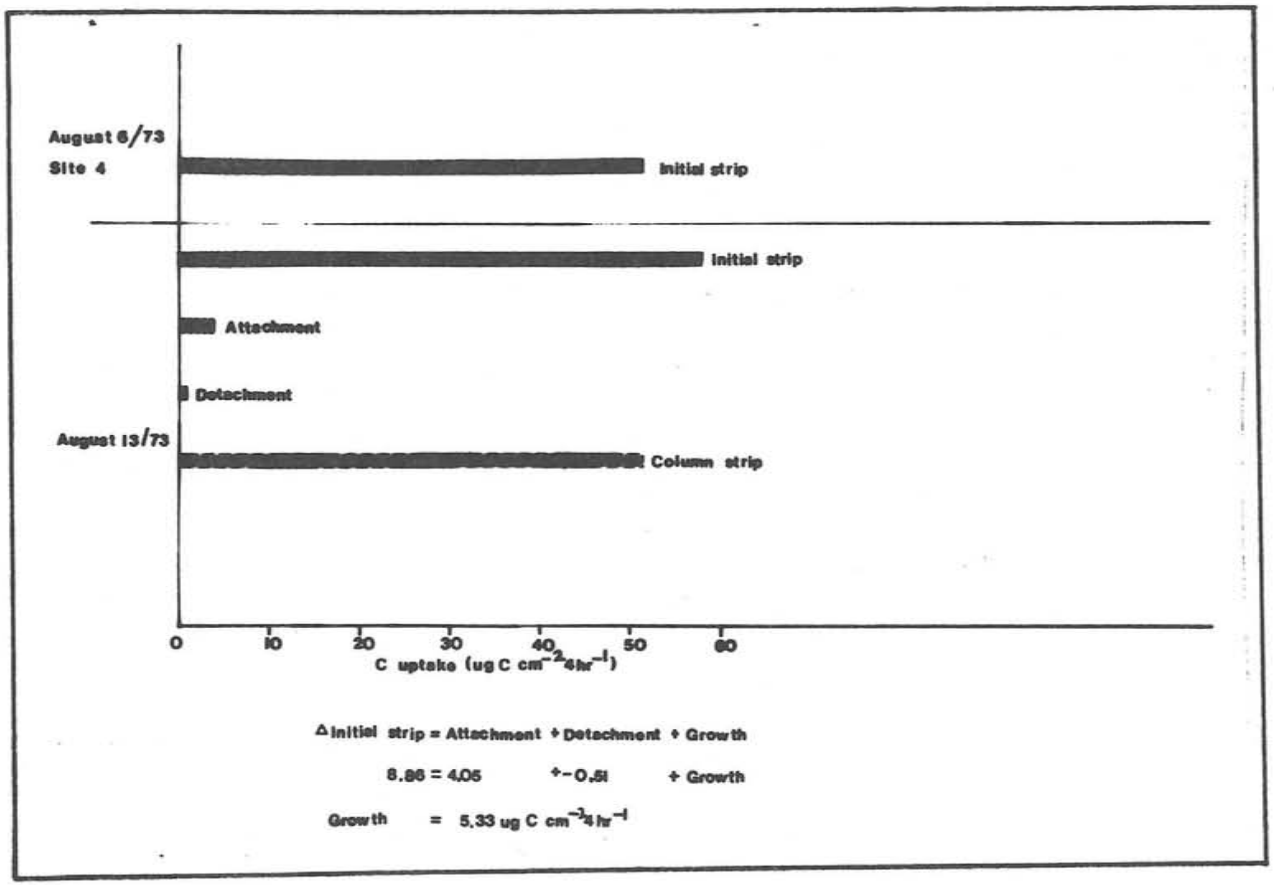


FIGURE 7. Measurement of Change in Carbon Uptake due to Attachment, Detachment and Growth of Epiphytes.

The Effects of Prescribed Burning on *Phragmites communis* Trin. in the Delta Marsh

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Objectives

1. To determine the effect of prescribed burning on *Phragmites* and the associated flora in terms of changes in the plant species composition and an increase or decrease in the faunal population.

2. To investigate whether the density of *Phragmites* can be reduced by burning and under what conditions and intervals.

3. To monitor microclimate on burned and control areas to formulate differences.

4. To determine if fall burning reduces snow accumulation.

Results

Vegetation

Data from 1970-72 indicated that there was little change in vegetation composition after burning and that the density of live cane increased.

The highlight of this year's work was that, on site MWB, *Phragmites* was drastically set back. The site had been burned on July 29, 1972 when the density of live shoots was 77.6/m^2. The live cane was killed but did not burn. The dried cane was subsequently burned on August 23, 1972 at which time the new shoots averaged 26 cm in height. When resampled in the first week of August 1973, the density was 35.2/m^2, a reduction of 45.3% from the previous year. There was a corresponding increase in abundance of the other species recorded on the site, particularly *Sonchus* sp., *Cirsium* sp. and *Mentha arvensis*. *Atriplex patula*, not present previously, had a frequency of 35% (Table 1).

Twice burning during one growing season appears to be a means of at least temporarily reducing the density of *Phragmites*. The meteorological records and vegetation data are compiled and this type of burning regime could be duplicated given the same conditions. However, I predict that

TABLE 1

Frequency of Species Expressed as a Percentage of Occurrence over Quadrats Sampled[1] -- Marsh Wren Bay Site[2]

	Burn			Control		
	1971	1972	1973	1971	1972	1973
Phragmites	100	100	95	100	100	100
Sonchus	50	55	100	57	62	67
Urtica	15	19	37	12	17	23
Cirsium	70	68	90	70	74	74
Mentha	70	73	86	73	75	79
Stachys	66	51	25	60	60	58
Lycopus	34	27	21	31	35	32
Atriplex	0	0	35	0	0	0
Chenopodium	0	0	5	0	0	0

[1]Each percentage entered in the columns in based on 40 randomly thrown quadrats.

[2]Marsh Wren Bay site was burned July 29, 1972, August 23, 1972 and May 14, 1973.

the density of the *Phragmites* will increase substantially in the next (1974) growing season, even if it does not return to the preburn densities.

In 1973 there was an overall reduction in heights of *Phragmites* (Table 2); no stems were recorded over 300 cm in height, whereas stems 300+ cm were not uncommon at the peak of growth in the previous two years. This held true on burn sites and controls and I surmise it is due to the lack of precipitation during the growing period.

The height of *Phragmites* was significantly reduced on a site which had been repeatedly burned for three years in comparison with the unburned control. Superfically, the density appeared to be reduced but quadrat data did not bear this out. This appearance was due not only to the reduced height of the stand but also the stunted, thin-stemmed nature of the *Phragmites*, although this was not quantified. Annual burning may be a means of controlling *Phragmites*, *i.e.*, setting back height. However late spring (May 15-30) burning was prescribed for this site and this may not be the preferred time to burn in regards to other management objectives.

TABLE 2

Average Heights (cm) of *Phragmites* at Peak of Growth (August)

	Burn			Control		
	1971	1972	1973	1971	1972	1973
MR	173	170	114	175	173	169
MWB	189	[1]	142	188	188	186
BC	187	183	182	180	184	182
BLN Is.	191	187	173	193	188	186
BLS Is.	186	187	182	189	187	179

[1]Data are available on heights of *Phragmites* on this site before it was burned July 29, 1972 but, as this is not at the peak of growth, it was not included.

From the data analyzed for five sites, there is little change in density of *Phragmites*, which increased rather than decreased (Table 3). There is no correlation between burning and the percent of *Phragmites* with inflorescence on any of the sites. It was earlier hypothesized that burning would stimulate flowering.

There was a marked increase in frequency of *Melilotus* (sweet clover), *Medicago* (alfalfa) and *Vicia* (vetch) on the drier areas of some of the sites. Several studies have recorded an increase in legumes after burning. Tables 4-6 include data on frequency for three sites.

Environmental Parameters

Pyrheliometers, hygrothermographs, thermistors and recorders were installed in March and removed in October. Again this year keeping the instruments functional was a full-time operation. Once one problem was solved, another would arise. A poisoning campaign eliminated the *Peromyscus* that had chewed the wiring. Other problems were mechanical rather than biological and repairs continually had to be made.

The accumulation of snow on burned areas versus unburned areas resulted in a strikingly inverse relationship. Accumulation was correlated with the time the area was burned previous to the first snowfall. The area burned last before the first snow accumulated the least snow. This held true back to July burns; burns earlier than July accumulated equal amounts of snow to areas unburned. Fig. 1 demonstrates this by pre-

senting data collected during February. Snow accumulation data plotted during the winter months show that the last burn before the first snow lost the snow (wind, evaporation, melting) more quickly.

Deer

The deer observations have continued to show a positive response from the deer to burning. Canadian Forces Base at Portage will continue their aerial censusing of the deer herd for me this winter. Findings from the small mammal data have not changed from last year's results.

The collection of field data has been terminated except for observations on deer use of sites. This study is now being written up, with hopes of having a completed copy by early spring 1974.

TABLE 3

Average Density of *Phragmites* Stems/M^2 in Selected Sites[1]

Site		Burn			Control		
		1971	1972	1973	1971	1972	1973
MWB (Burned July 29, 1972, August 23, 1972 and May 14, 1973)	Live:	63.8	77.6	35.2	63	75.1	62.1
	Dead:	34.6	73.3	0	60.3	69	67.9
MR (Burned May 15, 1972, October 13, 1972 and April 3, 1973)	Live:	28.2	29.2	24.6	31.2	26.6	27
	Dead:	38.4	0	1.9	40.5	41.2	47.9
BC (Burned October 10, 1971 and August 15, 1972)	Live:	42.4	54.2	38.1	45.3	49.5	38.9
	Dead:	64.1	0.1	3.3	60.4	62.5	65.9
BLN Is. (Burned September 15, 1971 and May 20, 1973)	Live:	63.4	67	73.4	64.4[2]	57.6[2]	64.5[2]
	Dead:	21.4	3.1	1.25	20.8[2]	13.4[2]	18.8[2]
BLS Is. (Burned May 2, 1973)	Live:	63	62.4	77	64.4[2]	57.6[2]	64.5[2]
	Dead:	21.4	24.4	10.3	20.8[2]	13.4[2]	18.8[2]

[1]All sampling occurred in late July and early August.

[2]Same control was used for these sites.

TABLE 4

Frequency of Species Expressed as a Percentage of Occurrence over Quadrats Sampled[1] -- Marsh Road, Dike Site[2]

	Burn			Control		
	1971[3]	1972	1973	1971	1972	1973
Phragmites	70	72.5	66	80	81.2	68
Cirsium	80	98	61	90	95	80
Mentha	55	42.5	20	45	45	10
Stachys	45	70	43	37	61.6	32
Sonchus	85	100	78	91.8	91.8	76
Urtica	5	0	20	5	10	10
Lycopus	15	26.6	19	20	31.6	22
Teucrium	7.5	13.3	2	10	5	0
Aster	22.5	28.3	38	17.5	31.6	25
Typha	25	23.7	25	21.2	21.2	22
Melilotus	0	5	12	0	0	0
Scolochloa	25	20	25	25	25	25
Cicuta	1.2	0	8	3.7	3.7	10
Scirpus acutus	3.7	2.5	10	13.7	16.2	18
Carex	3.7	3.7	5	2	2.5	8
Potentilla	0	0	6	0	0	2
Hordeum	0	0	1	0	0	5
Rumex	0	0	0	0	0	1
Ranunculus	0	6	0	0	0	0

[1]Each percentage entered in the columns is based on 80 permanent quadrats.

[2]The Marsh Road, Dike Site is a marginal stand with the lowest density of *Phragmites* stems (55/m^2) and was burned May 15, 1972, October 13, 1972 and April 3, 1973.

[3]Burn 1971 data are before the site was burned.

TABLE 5

Frequency of Species Expressed as a Percentage of Occurrence over Quadrats Sampled[1] -- Blind Channel Loop Site[2]

	Burn			Control		
	1971[3]	1972	1973	1971	1972	1973
Phragmites	100	100	100	100	100	100
Cirsium	63	75	63	60	75	65
Mentha	30	35	58	28	22	26
Sonchus	90	95	86	90	90	96
Urtica	32	35	58	40	38	66
Lycopus	29	31	20	20	20	14
Teucrium	10	12	20	5	8	21
Carex	34	40	45	39	40	30
Vicia	0	0	10	0	0	1
Aster	2	0	16	0	0	11

[1]Each percentage entered in the colums is based on 120 randomly thrown quadrats.

[2]The Blind Channel Loop Site is an intermediate stand burned October 10, 1971 and August 15, 1972.

[3]Burn 1971 data are before the site was burned.

TABLE 6

Frequency of Species Expressed as a Percentage of Occurrence over Quadrats Sampled[1] -- Big Lake N. Island Site[2]

	Burn			Control		
	1971	1972	1973	1971	1972	1973
Phragmites	100	100	100	100	100	100
Cirsium	0	0	10	0	10	10
Mentha	5	0	14	5	15	12
Sonchus	30	10	36	10	5	11
Teucrium	10	0	17	20	35	32
Atriplex	0	0	90	0	0	5
Chenopodium	0	0	20	0	0	2

[1]Each percentage entered in the columns is based on 80 randomly thrown quadrats.

[2]Big Lake N. Island Site is a *Phragmites* island with very few other species present and was burned on September 15, 1971 and May 20, 1973.

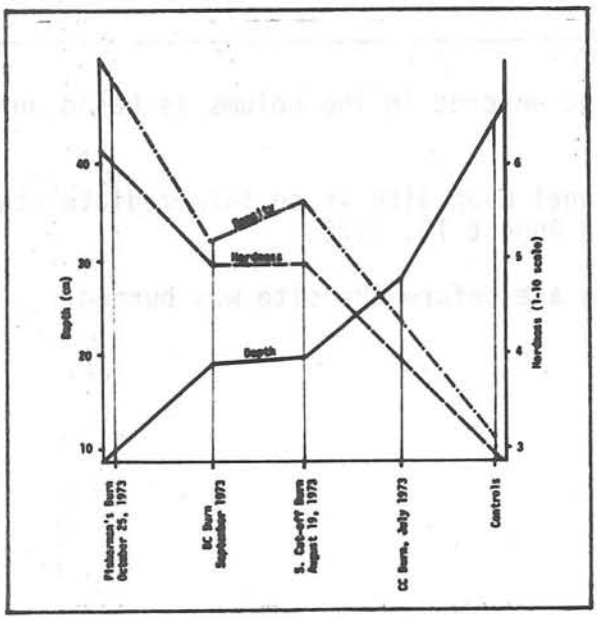

FIGURE 1. Averages of Snow Readings for February 1973. All snow data were collected using an NRC snow kit.

The Dynamics of Two Plant-Snail Associations in the Delta Marsh

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Introduction

The 1973 season's work was essentially a continuation of studies conducted at the Field Station in 1972. The results from that year, involving an examination of four submerged macrophyte species and 15 aquatic snail species by means of bottom sampling with an Ekman dredge, had suggested the existence of two positive plant-snail associations: that of *Potamogeton pectinatus* and *Physa gyrina* and that of *Potamogeton richardsonii* and *Lymnaea stagnalis*. The objective of the 1973 season's work was to question whether, indeed, these two apparent associations are real through a detailed attempt at quantification of the respective components of these associations.

Methods

Because of the difficult practical aspects of the problem, the sampling technique was crucial, since the validity of any conclusions drawn would largely depend on it. It was essential to sample simultaneously, rapidly and with a minimum of disturbance to the plants and associated macrofauna exclusive of the benthos. No suitably designed sampler was commercially available, so, with the requirements of the problem at hand, a sampler was designed and built. The basic principle of operation was modified from that proposed by Mackie and Qadri in 1971. The design itself was based upon studies of shoot density and contagion carried out in 1972. The sampler was essentially an isometric box of 0.5-m dimensions closed on all sides by 1.0-mm mesh screen. The bottom was open and consisted of a moveable and a stationary blade. On impact of the messenger with the trigger mechanism, the moveable blade was released. As it moved across toward the stationary blade, it carried a screen across with it to close the opening and prevent escape of the contents. In excess of 300 samples were taken with this sampler during the season; no problems were encountered with its operation or maintenance.

Two of the sites sampled during the 1973 season were at the Field Station close to the convenience of laboratory facilities. These sites were two sheltered ditches in the west marsh. Both had well-developed mutually exclusive stands of *Potamogeton pectinatus* and *P. richardsonii*.

Several samples, the number determined statistically, were taken from a small boat in each of the two plant stands in each site at two-week intervals commencing in May. The samples were sorted out for the floral and faunal components by hand and quantified.

Results

An examination of the phenology of the plants showed no asynchrony of development with respect to relative stem length increment in *Potamogeton pectinatus* and slight asynchrony in *P. richardsonii*.

Simultaneously the population density of *Physa gyrina* with time also showed no asynchrony in the two sites. *Lymnaea stagnalis* failed to reproduce simultaneously at both of the sites, site 2 showing a two-week lag behind site 1.

The relative association peaks did not coincide with the population density peaks. The number of individuals of *Physa gyrina*/gm dry weight of *Potamogeton pectinatus* (Fig. 1) was synchronized at both sites even though the absolute population density of this snail in site 2 was about 30% of that in site 1. The number of individuals of *Lymnaea stagnalis*/gm dry weight of *P. richardsonii* was out of phase by two weeks in the two sites (Fig. 2).

An examination of plant dry weight increment/unit area with time showed that *P. pectinatus* (Fig. 3) was developing in phase although in the latter part of the season the plants in site 2 exhibited more weight increment due to more vigorous branching. The weight increment of *P. richardsonii* was out of phase by two weeks (Fig. 4), coinciding with the lag observed in the association peaks.

It can be concluded that these associations appear to be real and that the two components of each association are synchronized with respect to each other in time. Since the associations appear to be linked to the growth cycles of the host plants, it is possible that plant-originated biochemical factors are responsible for at least the initiation of these associations. The presence of such antithetical relationships would appear to minimize the competition between the two major grazers on the two respective plant hosts.

References

Mackie, G. L. and S. U. Qadri. 1971. A quantitative sampler for aquatic phytomacrofauna. Journal of the Fisheries Research Board of Canada, 28: 1322-1324.

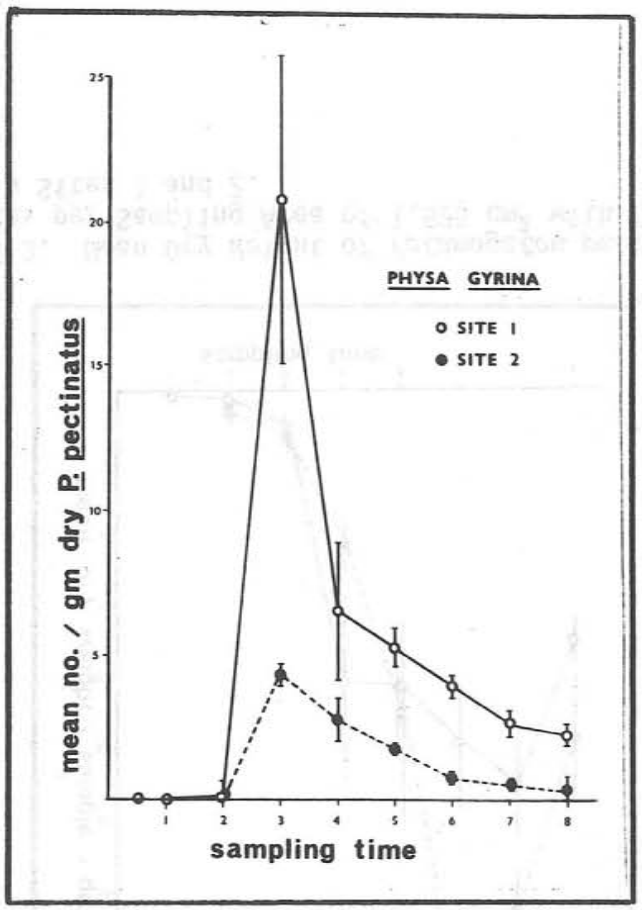

FIGURE 1. Mean Number of Individuals of *Physa gyrina* per Gram Dry Weight of *Potamogeton pectinatus* with Time in Sites 1 and 2.

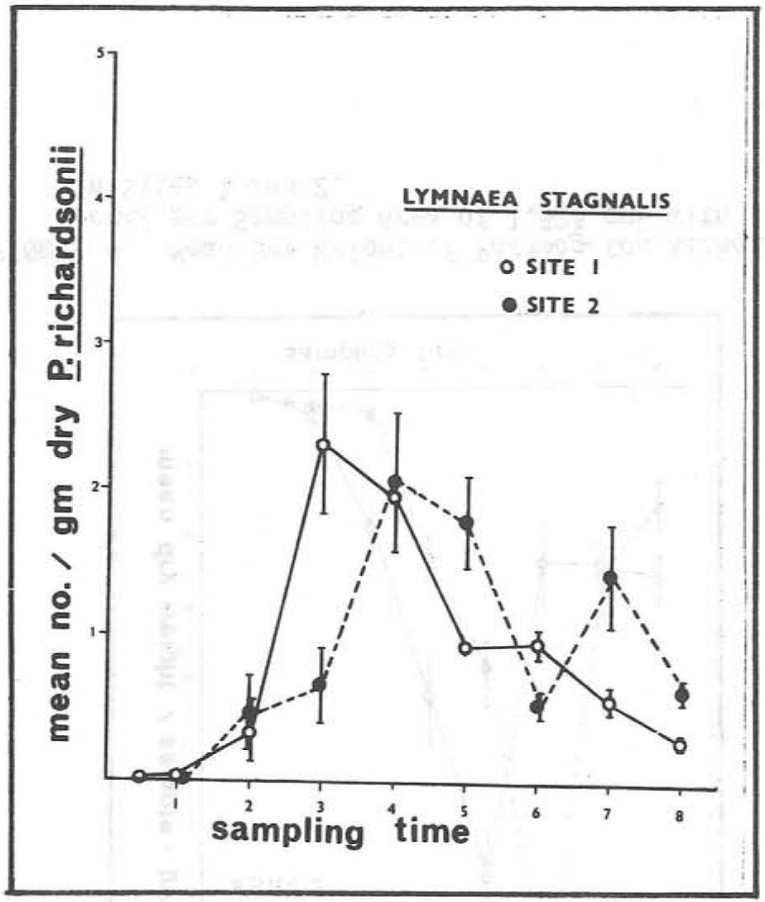

FIGURE 2. Mean Number of Individuals of *Lymnaea stagnalis* per Gram Dry Weight of *Potamogeton richardsonii* with Time in Sites 1 and 2.

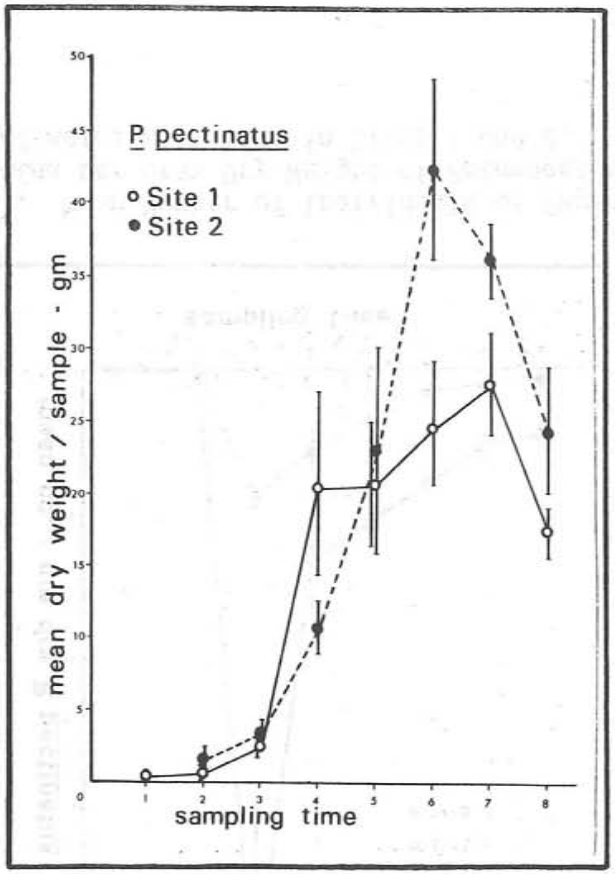

FIGURE 3. Mean Dry Weight of *Potamogeton pectinatus* per Sampling Area of 1,525 cm^2 with Time in Sites 1 and 2.

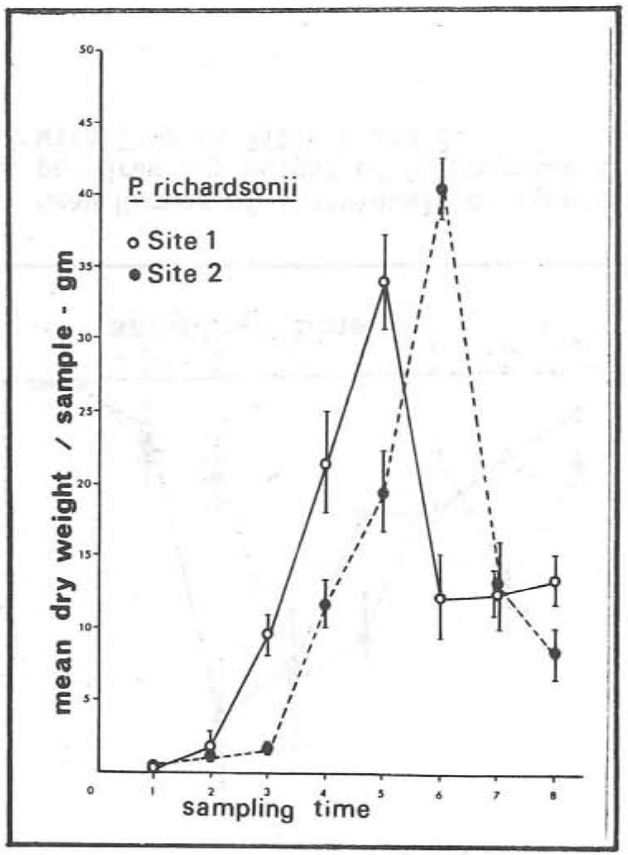

FIGURE 4. Mean Dry Weight of *Potamogeton richardsonii* per Sampling Area of 1,525 cm^2 with Time in Sites 1 and 2.

Some Aspects of the Phenology of Selected Marsh Species

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Objectives

To investigate patterns of the life cycle of *Atriplex patula*, *Rumex maritimus* var. *fueginus*, *Senecio congestus* and *Chenopodium rubrum* and the effects of differing water levels on the ecology of these species.

Introduction

These species occur in many marshes in southern and northern Manitoba where they are involved in succession with changing water levels. They are widely distributed throughout the northern hemisphere and are presumably phenotypically and/or genotypically variable. The purpose of this investigation is to study the ecology of selected populations in Delta Marsh subjected to changing water levels and to attempt to correlate field performance with responses under controlled conditions.

Methods

Eight sites were selected and studied with respect to the species under consideration. Four of these sites, designated 1, 2, 4, and 8, were naturally occurring ponds or sloughs within *Phragmites* or *Scirpus* marsh. These areas were frequently flooded after heavy rains, often held standing water and did not dry up until late summer.

Three of the sites, 3, 6, and 7, were areas of mud exposed at the edges of man-made borrow pits. They were often damp and muddy but seldom flooded. Site 6 had to be abandoned during field work as wave action destroyed the mud ledge under investigation by undercutting. The area of exposed mud in these sites increased as water levels in the borrow pits dropped during the summer. The last site, 5, was a small area, approximately 20 x 8 m bordering a drainage ditch and enclosed by *Typha* and *Phragmites* marsh on the other borders. This site was well above the level of water in the ditch and was never flooded.

The nature of the sites made vegetation analysis difficult but in sites 2, 3 and 5 species frequency was estimated using 50 or 100 0.25-m^2

quadrats thrown at random and line transects across the two diagonals of a 5-m square. Species were recorded every 5 cm along the transects.

Soil samples were taken in each site in May and late June and their pH, moisture content and organic content measured. Three replicates of each analysis were made per sample and the results averaged.

Phenological observations on the four species were made throughout the summer. These included time and duration of germination, seedling mortality, vegetative growth, flowering and fruiting. Individual plants of each species were staked in several sites and measurements of height, leaf number, length and breadth of longest leaf and rosette diameter or spread were made at two to three-week intervals. The flowering stage of each plant was assessed on a 0-10 scale (Turesson, 1930) and, in the case of *Senecio congestus*, the number of flower heads in the terminal section of the inflorescence was counted. Where applicable, the water depth at each staked plant was measured. Nineteen *Senecio congestus*, 60 *Rumex maritimus*, 50 *Atriplex patula* and 40 *Chenopodium rubrum* plants were staked. In late summer 15 new *Senecio congestus* seedlings were staked and measured.

Twenty to forty plants of each of the four species were transplanted from each of three sites into three experimental pits. One was maintained at a constant water level; in the second the level was raised by approximately 5 cm per week, and in the third the water level was not manipulated so that it fell through the summer and the pit was dry by mid-July. The bottom of the pits sloped at an angle of 20-30° so the plants were subjected to different water levels. Measurements of plant height, water depth, leaf number, length and breadth of longest leaf and flowering stage were made at three to four-week intervals.

Results

All the results of the observations and experiments are in the process of analysis and therefore only preliminary results can be given.

Vegetation Analysis

The line transect data showed that site 2, dominated by *Chenopodium rubrum*, had only three other species present. Site 3 contained 14 species and was also dominated by *C. rubrum* but there was 72% bare ground. In site 5 vegetation cover was 95% and the vegetation was co-dominated by *Senecio congestus* and *Aster brachyactis* (Table 1).

Soil Analysis

In all sites except site 5, pH fell between May and June (Table 2). This may be a reflection of the fact that moisture content rose in all sites except 5 over this period. This rise in moisture content was presumably the result of the low winter rainfall and dry spring conditions

TABLE 1

Vegetative Analysis of Three Sites

Species	Percentage Frequency		
	Site 2 (n = 287)	Site 3 (n = 297)	Site 5 (n = 296)
Bare ground	0.34	72.03	4.72
Chenopodium rubrum	65.15	12.45	
Atriplex patula		1.68	10.47
Senecio congestus		0.67	28.71
Rumex maritimus		0.67	12.16
Hordeum jubatum		6.73	2.96
Salicornia rubra		1.68	
Aster brachyactis		1.34	28.71
Rununculus cymbalaria		0.67	9.45
Beckmannia syzigachne		0.33	
Eleocharis palustris		0.33	
Melilotus alba		0.33	
Puccinellia nuttalliana	0.69	0.33	0.33
Sonchus arvensis		0.33	2.36
Typha latifolia	8.36	0.33	0.33
Scolochloa festucacea	25.43		

followed by high June rainfall (which was experienced in Manitoba). Organic content rose in all sites except 5 and 7.

The differences observed in site 5 may be due to the fact that only in this site is anything approaching a "true" soil found. Sites 3, 6, and 7 consist of mud, while sites 1, 2, 4 and 8 have mud-mixed decaying organic material. The former sites are characterized by high pH, low moisture content and low organic content; the latter by lower pH and relatively higher moisture and organic contents.

Phenological Observations

An outline of the phenology of each species is given in Fig. 1.

Germination and Survival

Rosettes of *Senecio congestus* of up to 30 cm in diameter were observed in April when there was still snow on the ground. By early

TABLE 2

Soil Analysis at Sites 1-8 (n = 3)[1]

		Site Number 1	2	3	4	5	6	7	8
pH:	May	7.50	8.17	8.17	6.97	7.03	8.13	7.97	7.60
	June	7.37	7.87	8.12	6.87	7.57	7.85	7.83	7.67
Moisture content:	May	81.80%	86.78%	32.00%	77.63%	77.06%	26.48%	32.38%	60.42%
	June	98.62%	98.49%	74.30%	98.26%	74.30%	67.14%	34.10%	69.76%
Organic content:	May	33.81%	48.21%	5.04%	37.82%	37.35%	1.59%	8.14%	16.00%
	June	56.98%	51.03%	6.99%	43.26%	35.82%	3.24%	6.42%	19.84%

[1]pH measured with a Radiometer pH meter. Organic content determined by ignition and moisture by oven drying at 160^0 to constant weight.

May rosettes of *S. congestus* and *Rumex maritimus* were large and often abundant. No germination of *Senecio congestus* occurred until mid-July after fruiting had commenced and it is believed that most, if not all, rosettes overwintered. The failure to observe *Rumex maritimus* seedlings in April and May also indicates overwintering of rosettes in this species. Some germination occurred from late June until early August. All these plants flowered but were considerably smaller than the overwintered plants. Further germination took place in late August and September and it is likely that these seedlings overwinter. Both winter and summer annual generations of *R. maritimus* would appear to be present at Delta Marsh.

Atriplex patula and *Chenopodium rubrum* plants were first observed at the end of May and it is unlikely that any plants overwinter. No seedlings were observed in open water but, as falling water levels exposed new areas of mud, germination occurred, first under *Phragmites* stands in site 1. As the wetter sites dried up, germination of *C. rubrum* was rapid on the detritus-covered pond bottoms. In site 2 seedling patches of both species were seen on 16 June. This area was flooded subsequently and all seedlings killed. No further germination was noted until mid-July. *Atriplex patula* plants were more abundant under occasional stands of *Scolochloa festucacea, Phragmites communis, Typha latifolia* and *Scirpus acutus* than in the open areas where *Chenopodium rubrum* dominated. Neither species occurred under very dense *Scirpus acutus* stands.

In several sites seedling patches of these two species were counted and marked to estimate survival. In *Chenopodium rubrum* mortality ranged from 0 in a patch of 9 seedlings (density 0.45 plants/cm^2) to 93.62% in a patch of 162 (density 1.62 plants/cm^2). Average mortality was 31.86% (n = 6). In *Atriplex patula* mortality ranged from 0 to 46.15% but appeared independent of seedling density. Average mortality was 23.38% (n = 9).

Vegetative Growth and Flowering

Rumex maritimus plants tended to be taller in the sites where there was standing water in spring (1, 4 and 8) (Fig. 2). Leaf number was lower in these wet sites than in drier ones. Although height differences between all the sites were highly significant in early summer, they became less apparent and were non-significant by mid-summer (Table 3). Flowering was considerably delayed in the wettest sites, 1, 4 and 8, compared to the drier sites, 3, 5, and 7 (Fig. 2). Differences in flowering time between the populations remained highly significant (Table 4).

Senecio congestus plants were less variable between sites but flowering was slightly delayed in the damper site 1 as compared to site 8. Seedlings observed in September and October showed differences in height, leaf number and leaf length but generally these differences reflected differences in germination time between sites.

Atriplex patula plants were not found in the wettest areas especially in the wetter sites and showed less variation between sites. The tallest plants were found in the sites with the densest vegetation, sites 1 and 5.

TABLE 3

Analysis of Variance of Height in *Rumex maritimus*

	df	MS	F	P
16-28 June:				
Between sites	3	1158.27	17.89	<0.001
Within sites	9	72.73	1.12	ns
Remainder (error)	27	64.75		
5-14 July:				
Between sites	3	485.12	3.49	0.05-0.01
Within sites	9	163.76	1.18	ns
Remainder (error)	27	139.09		
20-29 July:				
Between sites	3	134.87	0.4528	ns
Within sites	9	239.90	0.8054	ns
Remainder (error)	27	297.85		

TABLE 4

Analysis of Variance of Flowering Time in *Rumex maritimus*

	df	MS	F	P
5-14 July:				
Between sites	3	51.57	46.72	<0.001
Within sites	9	1.18	1.07	ns
Remainder (error)	27	1.10		
20-29 July:				
Between sites	3	63.29	13.42	<0.001
Within sites	9	3.06	0.65	ns
Remainder (error)	27	4.72		

df - degrees of freedom

MS - mean square

F - $\frac{\text{F ratio mean square}}{\text{residual mean square}}$

P - probability

Much shorter plants were found in sites 3 and 7 where the vegetation was more open. Here the plants frequently spread along the ground. Leaf length was also much greater in sites 1 and 5. One leaf in site 1 reached 11.5 cm. Leaf number was high in site 1 where some plants had over 400 leaves but was also high in site 3 where large prostrate plants often developed. Flowering was delayed in sites 1, 3 and 7 compared to 5 and 8 but this was much less marked in *Senecio congestus* or *Rumex maritimus*.

Chenopodium rubrum plants behaved very similarly to *Atriplex patula* plants though they lagged phenologically by about two weeks. The tallest leafiest plants were found under *Phragmites* in site 1 and these plants also had the longest leaves, one reaching 12.5 cm.

Experimental Data

Many plants failed to survive transplanting into the pits and plants rarely grew as luxuriantly as plants in the original sites. However, sufficient plants survived and grew for some meaningful data to be collected and these are now being analyzed.

From the preliminary results it would appear that the pit data correlate well with data from plants investigated in their original sites. Plant height increased with water depth in *Rumex maritimus* while leaf number declined. Flowering was delayed in all species with increasing water depth. Only *R. maritimus* and *Senecio congestus* plants survived when submerged. In *Rumex maritimus* the leaves often died but the plants regenerated from the base. *Atriplex patula* and *Chenopodium rubrum* plants failed to survive if their leaves were submerged. In the pit where the water level was gradually raised, these plants were killed by the rising water even if well established before being submerged.

It would appear that, while *Rumex maritimus* and *Senecio congestus* are true marsh annuals able to survive flooding in both natural and experimental sites, *Atriplex patula* and *Chenopodium rubrum* are more ruderal species which have invaded the borrow pits and marsh shorelines from drier sites. These species cannot tolerate submersion of their leaves even when well established and therefore must survive periods of inundation in the seed stage.

References

Turesson, G. 1930. The selective effect of climate upon the plant species. Hereditas, XIV: 99-152.

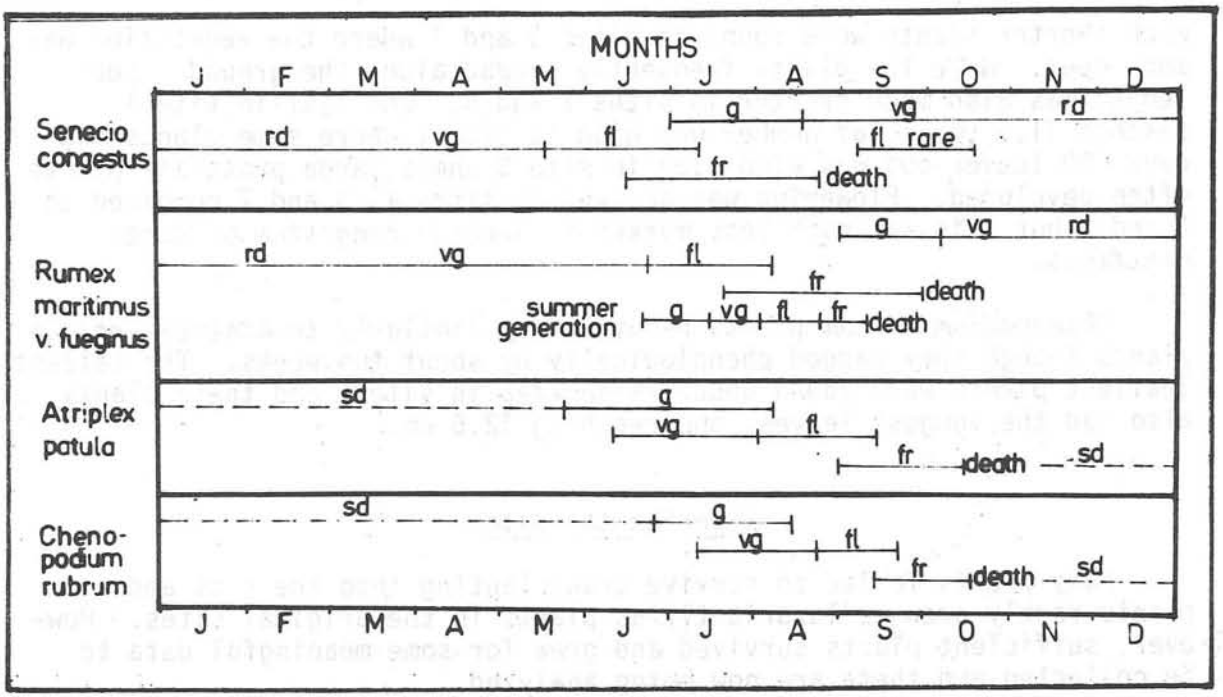

FIGURE 1. Phenology of *Senecio congestus*, *Rumex maritimus* var. *fueginus*, *Atriplex patula* and *Chenopodium rubrum* in Delta Marsh in 1973. (rd = rosette dormancy, sd = seed dormancy, vg = vegetative growth, fl = flowering, fr = fruiting, g = germination).

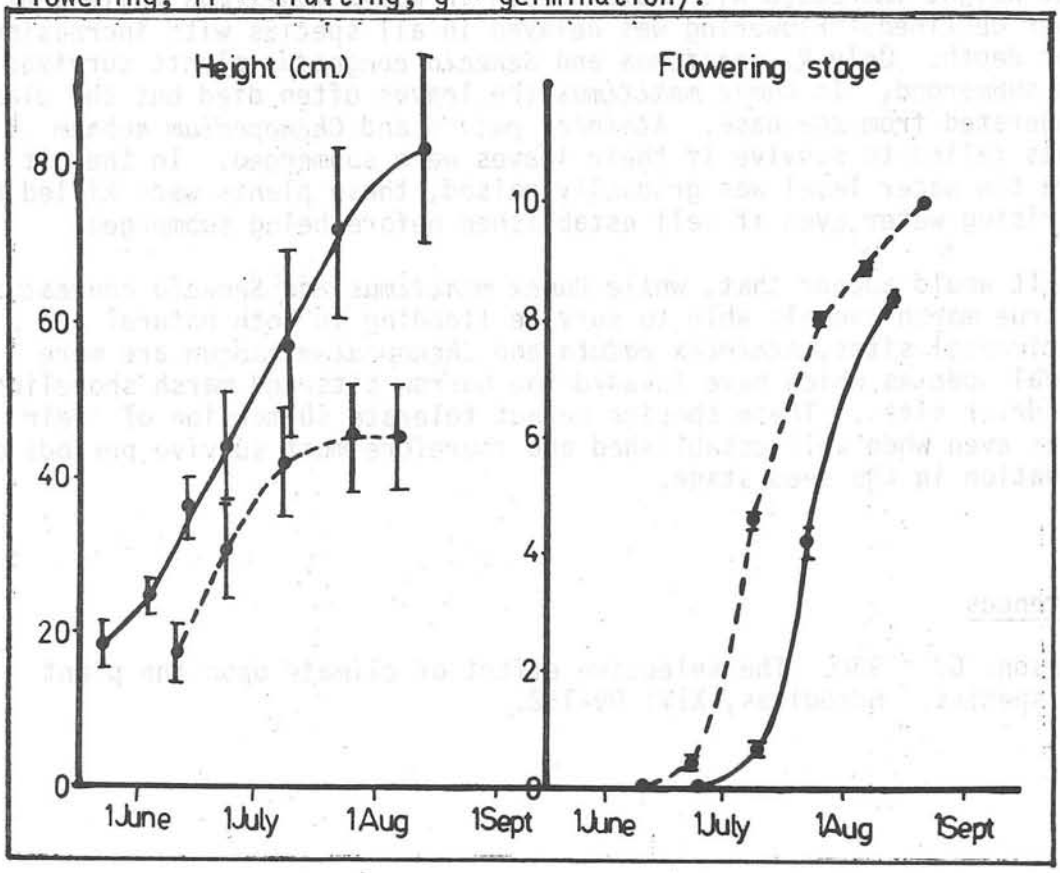

FIGURE 2. Height and flowering stage of *Rumex maritimus* plants in Wet Site 1 (——) and Dry Site 3 (---). (Vertical lines give 2x standard error of the mean).

Amino Acid Uptake by Bacterial Populations in the Delta Marsh and Southern Lake Manitoba -- A Preliminary Report

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Introduction

The overall purpose behind the present study has been to acquire means of assaying planktonic bacterial populations in water and amounts of available dissolved organic material. Such values might then be considered as indices of water quality and perhaps a means of assessing the effects of the mixing of water masses of different origin in the Delta Marsh area of southern Lake Manitoba.

Materials and Methods

Two organic substrates were arbitrarily chosen for this research. These were the amino acids, aspartic acid and glutamic acid. The utilization of these two substrates was determined by measuring their uptake, in a uniformly ^{14}C labeled form, by planktonic bacteria. This involved the incubation of water samples from representative sites in the Delta Marsh and from inshore Lake Manitoba in the presence of increasing amounts of labeled substrates. Following such incubation at constant temperature, the heterotrophs were filtered out of the samples and the uptake of the substrate determined by liquid scintillation counting. In this manner the kinetics of uptake of each substrate could be examined and the maximum velocity (Vmax) of uptake of each substrate determined. Such Vmax values are indices of bacterial population size.

A number of similar experiments were conducted in which mixtures of lake and marsh water were used, in an attempt to superficially estimate the effects of one water type upon another.

Results and Discussion

For both glutamic acid and aspartic acid, in both marsh water and inshore lake water, the relationship between uptake of the substrate and the concentration of the substrate was asymptotic (Figs. 1 and 2), suggesting active uptake according to Michaelis Menten kinetics. For both substrates the velocity of uptake in marsh water achieved a much higher

maximum value than for lake water, indicating relatively higher bacterial populations and presumably higher levels of natural substrate in the former. Actual Vmax values were derived from linear Lineweaver-Burke transformations of these curvilinear relationships.

Such determinations of Vmax for glutamic acid in a number of water masses in the vicinity of the University Field Station at Delta Marsh showed considerable differences (Fig. 3). Essentially these values confirm what might logically be expected. Marsh water apparently has higher bacterial populations than lake water; certain areas in the marsh have higher populations than others and inshore lake waters have higher populations than offshore waters.

For experiments in which the kinetics of uptake of glutamic acid (Figs. 4 and 5) and aspartic acid (Figs. 6 and 7) were analysed in mixtures of equal proportions of marsh and lake water, intermediate Vmax values were obtained. This might be expected by simple dilution of marsh populations by lake populations. However, observed values (Table 1) were in fact lower than those that might be expected by dilution. Essentially the effect of lake water was to suppress bacterial activity beyond a level that might be expected by simple dilution.

TABLE 1

Comparison of Observed Vmax Values and Expected Vmax Values, as Determined from the Uptake of Two Amino Acids by Mixed Equal Proportions of Lake and Marsh Bacterial Populations

	Glutamic Acid	Aspartic Acid
Observed Vmax mgC m^{-3} $hr.^{-1}$	1.669	2.850
Vmax value expected by dilution mgC m^{-3} $hr.^{-1}$	1.935	4.812

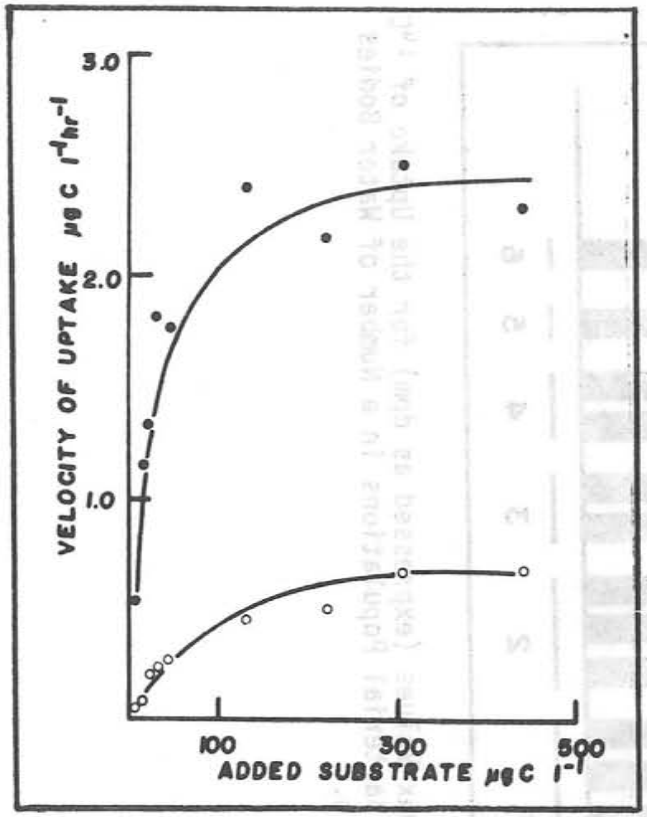

FIGURE 1. The Relationship between the Uptake of Glutamic Acid Carbon and Substrate Concentration in the Blind Channel (Delta Marsh) and Inshore Lake Manitoba. (Solid symbols = Blind Channel; Circles = Lake Manitoba).

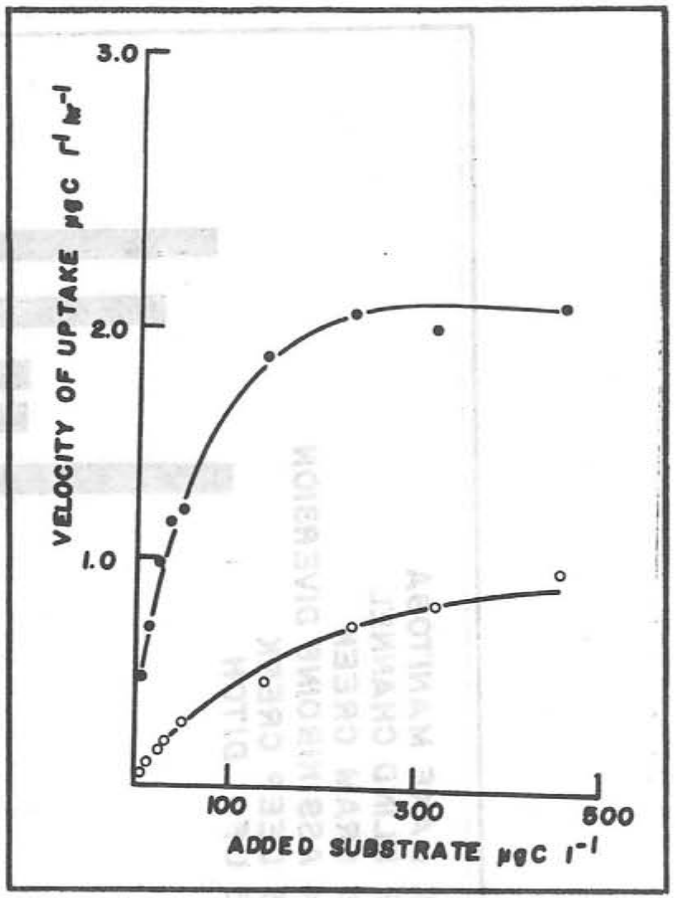

FIGURE 2. The Relationship between the Uptake of Aspartic Acid Carbon and Substrate Concentration in the Blind Channel (Delta Marsh) and Inshore Lake Manitoba. (Solid symbols = Blind Channel; Circles = Lake Manitoba).

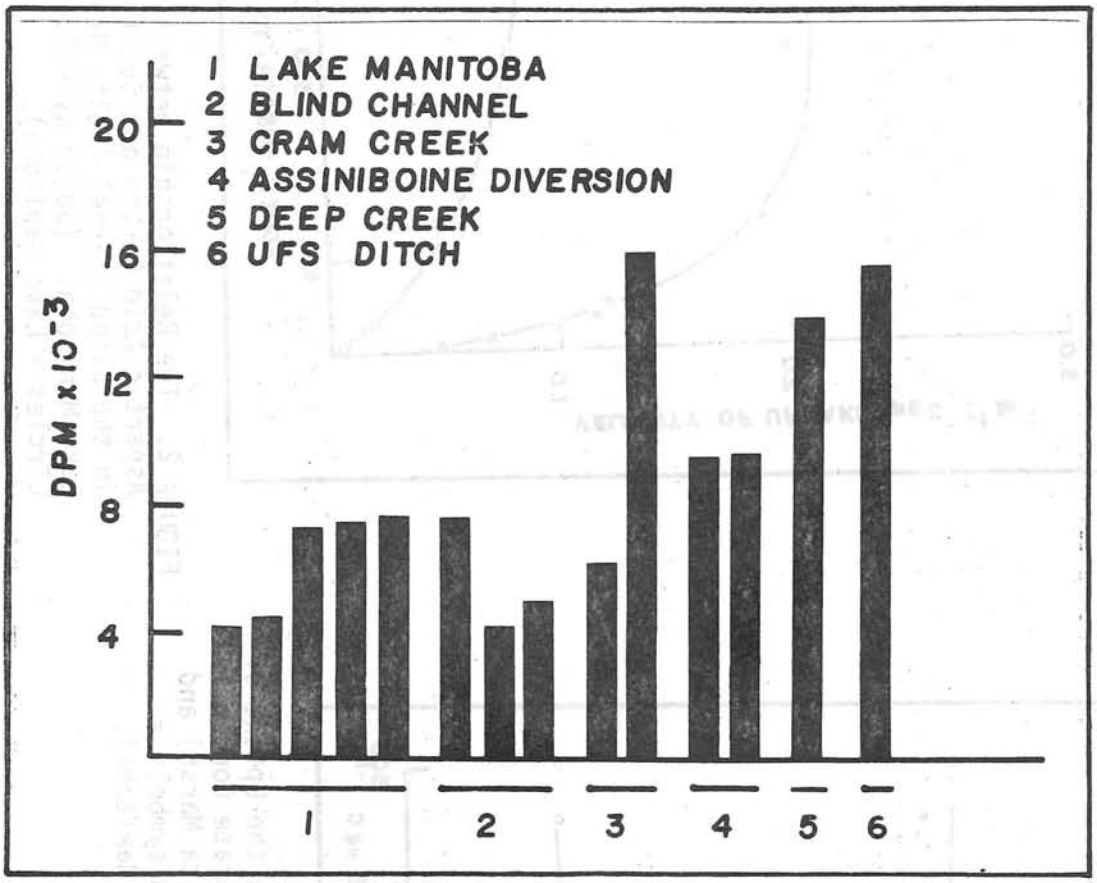

FIGURE 3. Relative Vmax Values (expressed as dpm) for the Uptake of ^{14}C Glutamic Acid by Bacterial Populations in a Number of Water Bodies in the Delta Marsh.

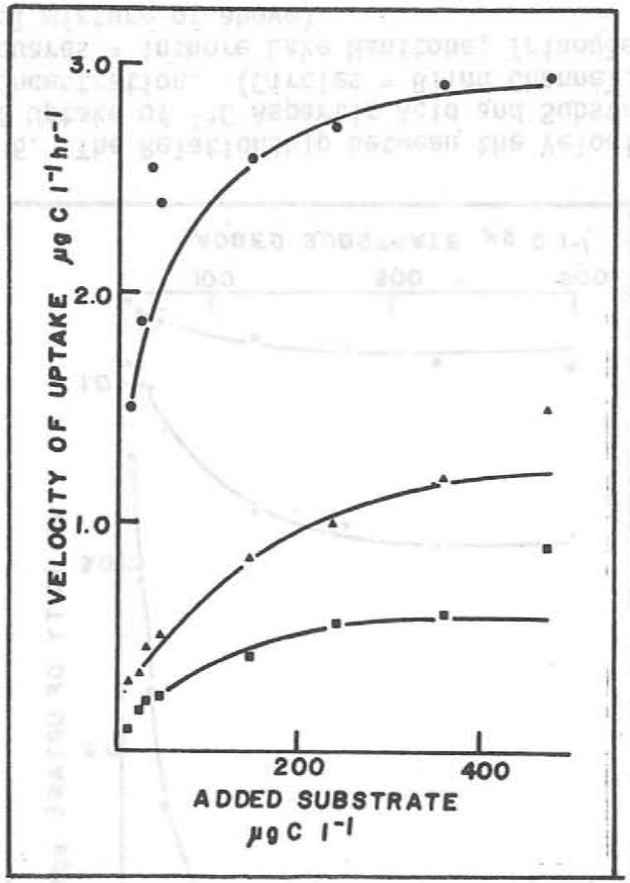

FIGURE 4. The Relationship between the Velocity of Uptake of ^{14}C Glutamic Acid and Substrate Concentration. (Circles = Blind Channel; Squares = inshore Lake Manitoba; Triangles = 1:1 mixture of above).

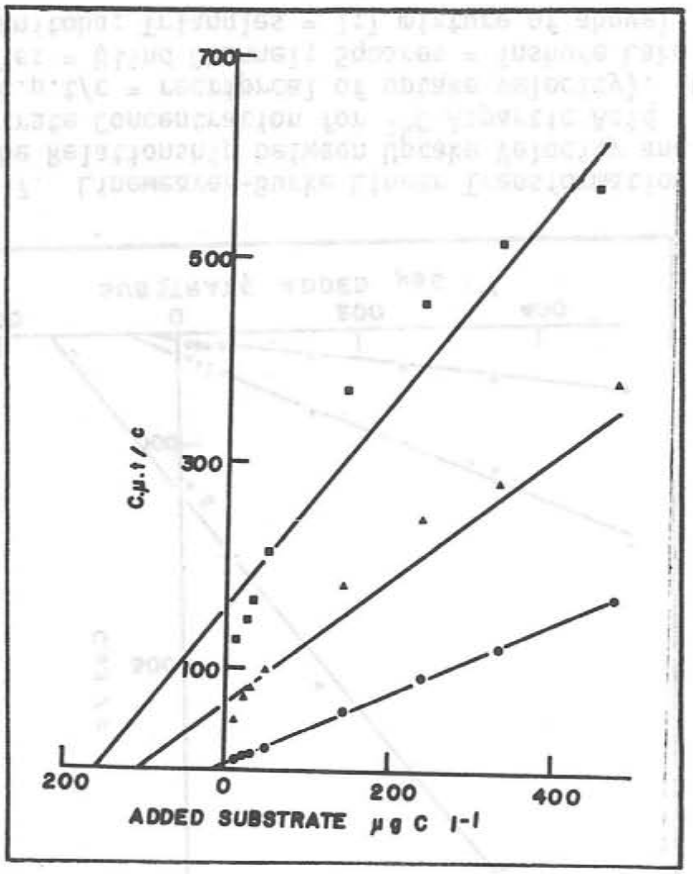

FIGURE 5. Lineweaver-Burke Linear Transformation of the Relationship between Uptake Velocity and Substrate Concentration for ^{14}C Glutamic Acid (c.µ.t/c = reciprocal of uptake velocity). (Circles = Blind Channel; Squares = inshore Lake Manitoba; Triangles = 1:1 mixture of above).

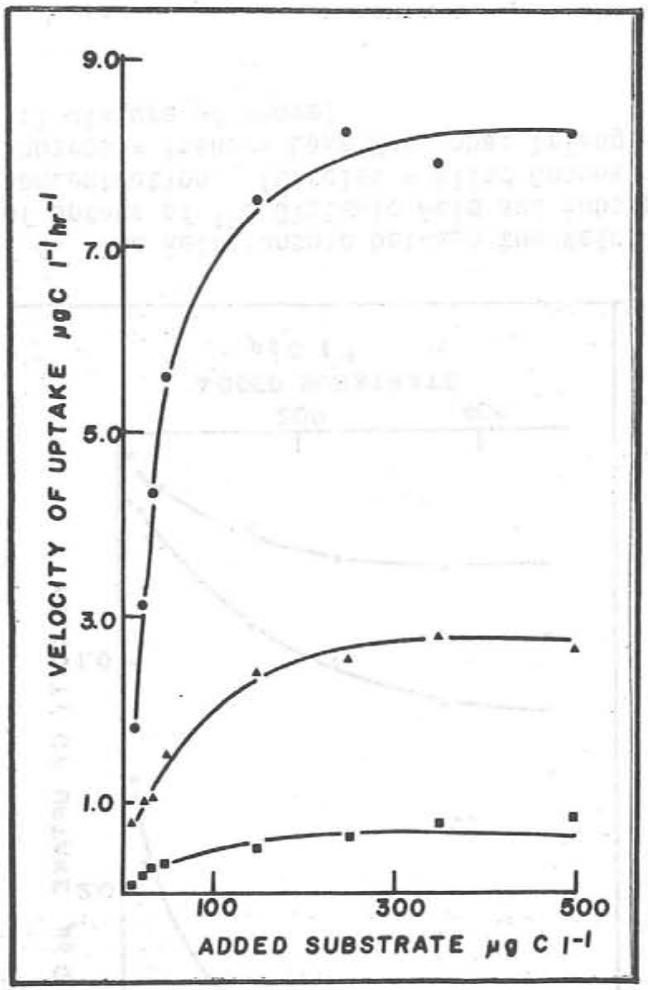

FIGURE 6. The Relationship between the Velocity of Uptake of ^{14}C Aspartic Acid and Substrate Concentration. (Circles = Blind Channel; Squares = inshore Lake Manitoba; Triangles = 1:1 mixture of above).

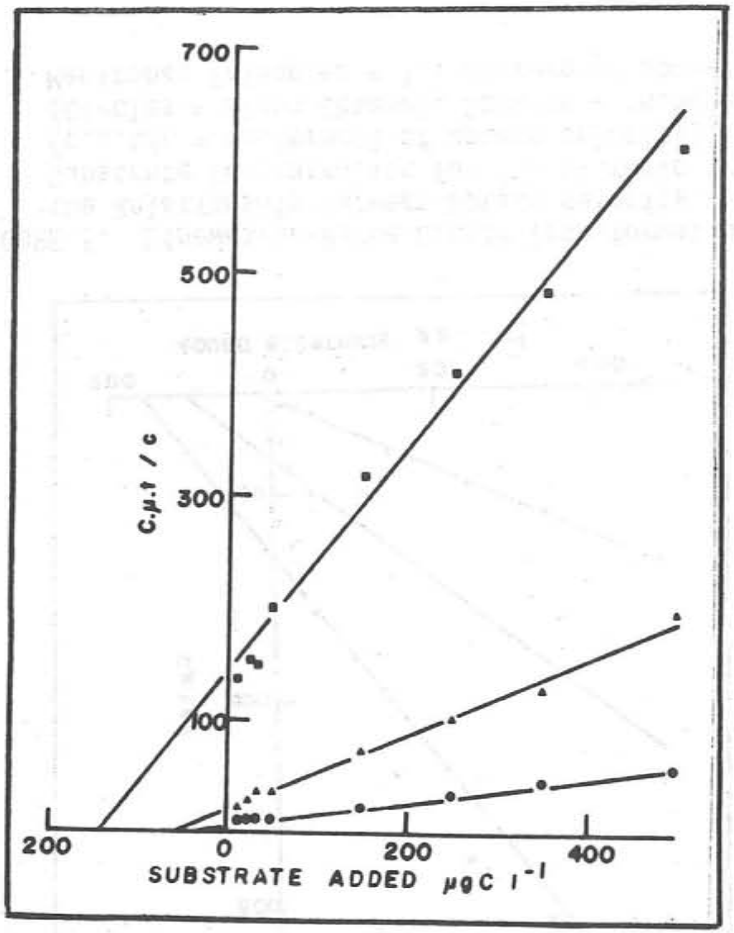

FIGURE 7. Lineweaver-Burke Linear Transformation of the Relationship between Uptake Velocity and Substrate Concentration for ^{14}C Aspartic Acid (c.µ.t/c = reciprocal of uptake velocity). (Circles = Blind Channel; Squares = inshore Lake Manitoba; Triangles = 1:1 mixture of above).

Productivity of the Benthic Fauna of Lake Manitoba

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Department of Zoology

Purpose

The purpose of this study is to assess the role of the benthic fauna in the productivity of the lake ecosystem, with emphasis on the trophic links between the benthos and commercially important fishes. Spatial and temporal variation in density, biomass, net production and energy flow are being considered. The area of study is that part of Lake Manitoba within approximately five miles of the southern shore, near the University of Manitoba Field Station at Delta Marsh.

Methods

From May to October 1973 sampling was conducted at monthly intervals at eight stations along two perpendicular transects (Fig. 1). The sampling stations, marked by buoys, were chosen with no prior knowledge of the benthic fauna present at those locations, but rather to provide a good coverage of the ranges of depth and exposure to wind effects (see Fig. 2).

Three sampling devices were used: (1) a multiple-corer (Hamilton, Burton and Flannagan, 1970) which takes four 12.6-cm^2 samples simultaneously; (2) a modified Ekman-type grab (Burton and Flannagan, 1973) which samples a 225-cm^2 area; and (3) a similarly modified Ekman-type grab of 520-cm^2 area.

Each month and at each station, four multiple-corer samples (yielding 16 cores) and two 225-cm^2 Ekman grab samples were collected. In June and August only, two samples were also collected with the 520-cm^2 Ekman grab at each station, so that comparison of results could be made with the Provincial Government study. To facilitate this comparison, these large Ekman samples were similarly treated, *i.e.*, washed through a 0.5-mm mesh net. Our other samples, from both small Ekman and corer samples, were washed through a 0.2-mm mesh, so that the importance of smaller organisms could be assessed. We also hope to assess the relative efficiencies of the three types of sampling devices used.

In June and July at all stations except 7 and 8, where the substrate was too hard, two or three additional core samples were obtained for

determination of vertical distribution of the fauna in the sediment. These cores were divided into 5-cm layers which were labelled and stored separately.

The organisms were fixed in 10% formalin for one week and then transferred to 70% alcohol for permanent storage. Samples were hand-sorted under a dissecting microscope.

In association with the biological samples, determinations were routinely made of temperature, pH, dissolved oxygen, transparency, alkalinity, hardness, chloride, suspended material and total dissolved solids. Also, at each time and station eight sediment cores were obtained for determination of particle-size structure and organic content. These sediment samples were frozen until analysis.

Results

The more than 500 benthic samples collected so far are currently being processed. Therefore, the results which can be presented are necessarily general and preliminary. It appears that the numerically dominant groups are, in order of abundance, Ostracoda, Nematoda, Chironomidae, Sphaeriidae, Gastropoda, Oligochaeta and Trichoptera. Other groups present, in relatively low densities, were Hirudinea, Hydracarina, Coelenterata, Ceratopogonidae, Culicidae and Ephemeroptera (Table 1).

TABLE 1

Percentage Abundance of Benthic Fauna
from Different Sampling Devices (Lake Manitoba, May-June 1973)

Organism	Multiple Corer	225-cm^2 Ekman grab	520-cm^2 Ekman grab
Ostracoda	39.50%	33.14%	1.25%
Nematoda	27.64%	27.43%	4.52%
Chironomidae	18.51%	22.70%	38.07%
Sphaeriidae	5.40%	5.06%	28.13%
Gastropoda	4.68%	4.80%	22.91%
Oligochaeta	3.67%	6.22%	3.87%
Trichoptera	0.10%	0.32%	0.17%
Others	0.50%	0.33%	1.08%

Estimates obtained with the multiple-corer and the 225-cm^2 Ekman

grab (with sieving through a 0.2-mm mesh net for both) were similar, indicating reliability of the abundance data yielded. Estimates from the 520-cm^2 Ekman samples, with sieving through a 0.5-mm mesh net, were quite different from the other samples, suggesting significant loss either in the sampling itself or in the sieving. The highest density estimates are obtained with the multiple-corer for all groups of animals, and the lowest with the 520-cm^2 Ekman grab with sieving through the 0.5-mm mesh net (Table 2). The highest densities were encountered at stations 1 and 5 and the lowest at stations 7 and 8 where the bottom is hard and sandy (see Table 3). At stations 1, 2, 3 and 4 the nematodes dominate, followed in order of abundance by ostracods and chironomids, whereas at stations 5 and 6 the ostracods dominate, followed by the chironomids and nematodes.

TABLE 2

Densities (number/m^2) from Different Sampling Devices
(All Stations, May-June 1973)

Organism	Multiple Corer	225-cm^2 Ekman grab	520-cm^2 Ekman grab
Nematoda	17,539.68	8,133.33	293.84
Oligochaeta	2,325.39	1,844.44	251.34
Gastropoda	2,968.25	1,422.22	1,488.84
Sphaeriidae	3,412.69	1,500.00	1,828.27
Ostracoda	25,301.58	9,827.55	80.96
Chironomidae	11,746.03	6,727.55	2,473.84
Trichoptera	55.55	96.88	10.96
Others	317.46	100.00	70.00

Analysis of cores sectioned to determine vertical distribution in sediment indicates (Fig. 3) that most organisms occur at depths of less than 10 cm in the sediment.

Planned Continuation

A set of samples similar in type and number to the summer samples will be collected in January or February 1974, in order that the seasonal pattern of benthic species composition and abundance can be assessed. Viscera of commercially important fish species caught in the south end of Lake Manitoba will be examined to determine which types of benthic

organisms are being selected and are therefore important in fish production.

The assessment of benthic productivity in relation to its importance in fish production requires additional studies, continuing from those described above, next summer (1974). In particular, determination of year-to-year variation in species composition and abundance at the same stations and some assessment of production in energetics terms are vital to the successful completion of this study.

References

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TABLE 3

Variation in Densities (number/m^2) with Different Sampling Devices (Lake Manitoba, May-June 1973)

Station	Multiple Corer	225-cm^2 Ekman grab	520-cm^2 Ekman grab
1	77,230.15	50,488.88	7,307.69
2	68,849.20	45,000.00	---
3	40,674.60	40,933.33	7,144.23
4	69,365.08	20,466.66	15,259.61
5	107,190.47	48,888.88	6,355.76
6	51,531.74	21,133.33	8,019.23
7	29,809.52	10,311.11	1,019.23
8	---	---	365.38

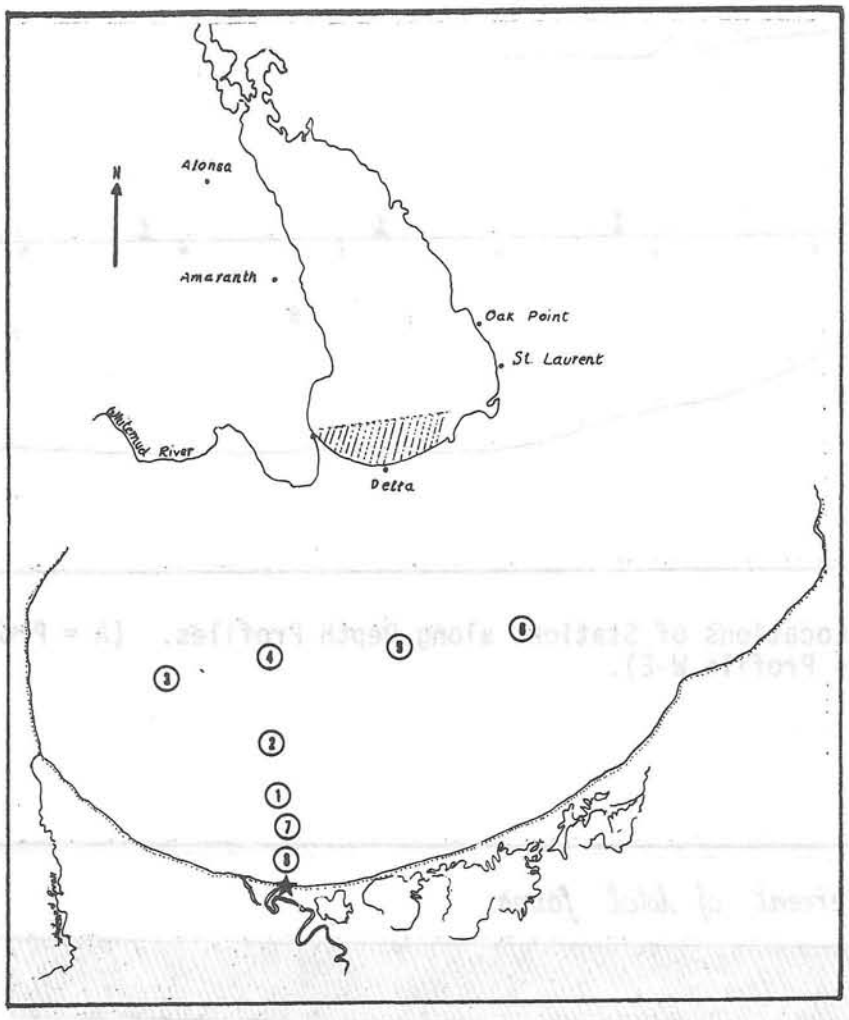

FIGURE 1. Maps of Lake Manitoba showing Study Area and Sampling Stations.

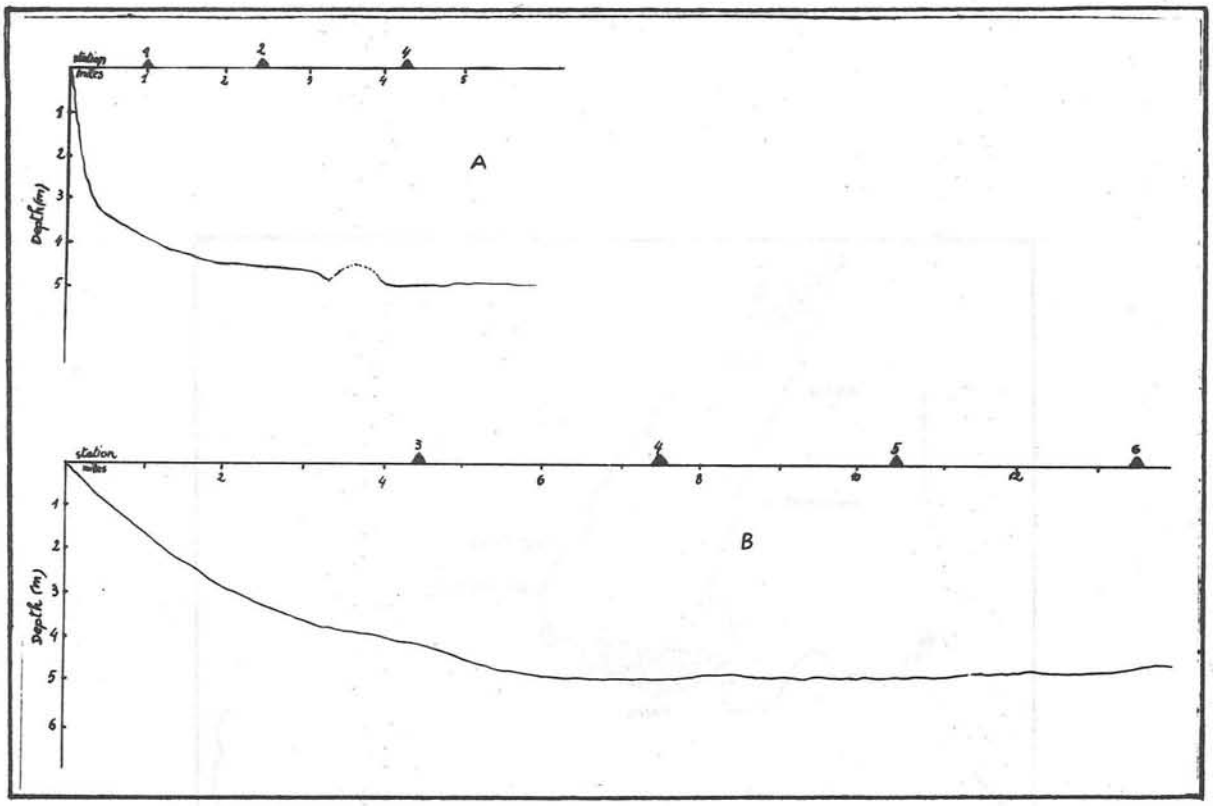

FIGURE 2. Locations of Stations along Depth Profiles. (A = Profile NW-SE, B = Profile W-E).

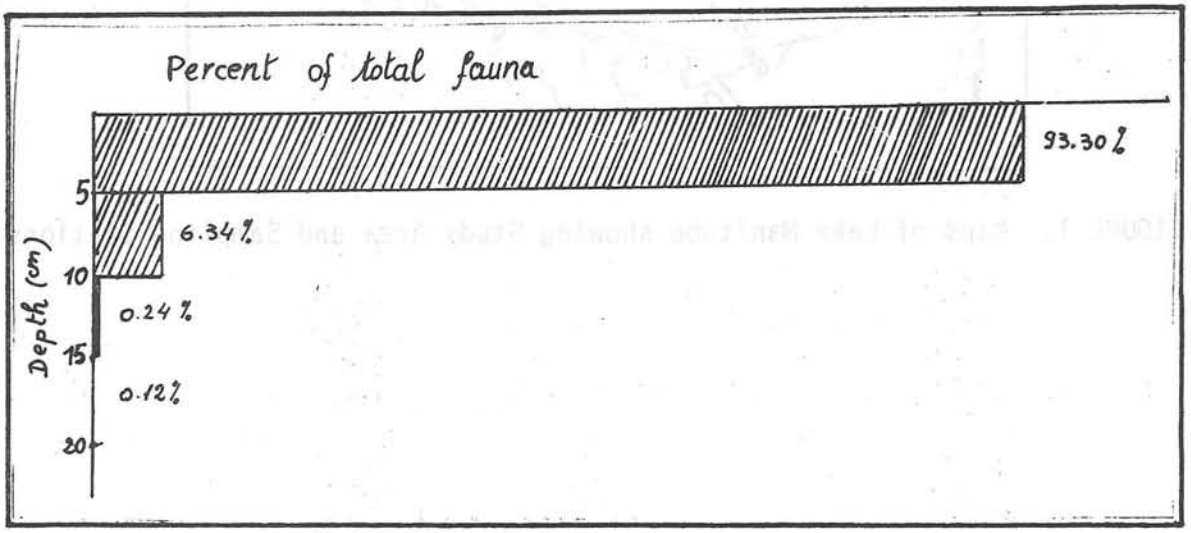

FIGURE 3. Vertical Distribution of Benthic Fauna (Lake Manitoba, May-June 1973).

Appendix I

Publications Resulting from Work at the University Field Station (Delta Marsh)

1. Walker, J. M. and E. R. Waygood. 1968. Ecology of *Phragmites communis*. I. Photosynthesis of a single shoot *in situ*. Canadian Journal of Botany, 46: 549-555.

2. Evans, R. M. and R. W. Nero. 1967. Sight record of Green Heron at Delta, Manitoba. The Blue Jay, 25: 184.

3. Tamplin, M. J. 1966. The glacial Lake Agassiz survey 1966: a preliminary report. University of Manitoba, mimeo, 19 pp.

4. Tamplin, M. J. 1967. The glacial Lake Agassiz survey 1967: preliminary report. University of Manitoba, mimeo, 7 pp.

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7. Watts, C. H. S. 1970. The larvae of Dytiscidae (Coleoptera) from Delta, Manitoba. The Canadian Entomologist, 102: 716-728.

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12. Allocated, but not yet fulfilled.

13. Allocated, but not yet fulfilled.

14. Badour, S. S. and E. R. Waygood. 1971. Excretion of an acid semialdehyde by *Gloeomonas*. Phytochemistry, 10: 967-976.

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19. McNicholl, M. K. 1973. Habituation of aggressive responses to avian predators by terns. The Auk, 90: 902-904.

20. McNicholl, M. K. 1973. Volume of Forster's Tern eggs. The Auk, 90: 915-917.

21. In preparation.

22. In preparation.

23. In preparation.

24. In preparation.

25. In preparation.

26. In preparation.

27. In preparation.

28. In preparation.

Appendix II

Theses Resulting from Work at the University Field Station (Delta Marsh)

Hominick, William Michael. 1969. Synchronization of life cycles of three new mermithids (Nematoda) with the chironomid (Diptera) hosts and some observations on the pathology of the infections. M.Sc. thesis, Department of Zoology, University of Manitoba, 102 pp.

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Hlynka, Leo Jurij. 1970. Helminths in *Rana pipiens* Schreber, and *Bufo hemiophrys* Cope from the Delta Marshes, Manitoba. M.Sc. thesis, Department of Zoology, University of Manitoba, 110 pp.

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Quaye, Martey Osabu. 1972. The taxonomy of the lung-worm *Rhabdias* Stiles and Hassall, 1905 (Nematoda), parasitic in *Bufo hemiophrys* Cope and *Rana pipiens* Schreber, and the interspecific relationship of helminths in the lungs of these amphibians. M.Sc. thesis, Department of Zoology, University of Manitoba, 93 pp.

Sproule, Thomas Albert. 1972. A paleoecological investigation into the post-glacial history of Delta Marsh, Manitoba. M.Sc. thesis, Department of Botany, University of Manitoba, 49 pp.

Macaulay, Alexander James. 1973. Taxonomic and ecological relationships of *Scirpus acutus* and *S. validus* (Cyperaceae) in southern Manitoba. Ph.D. thesis, Department of Botany, University of Manitoba, 213 pp.