ECOLOGY OF WILDRICE (*Zizania palustris* L.): Fruit Production and Habitat Relationships

by

Roger C. Garrod

A thesis
presented to the University of Manitoba
in partial fulfillment of the
requirements for the degree of
Master of Science
in
Botany

Winnipeg, Manitoba

ECOLOGY OF WILDRICE (*ZIZANIA PALUSTRIS* L.):

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ABSTRACT

The fruit production characteristics of commercially viable natural stands of wildrice (Zizania palustris L.) in eastern Ontario were quantified. Data collected included stem and panicle densities, numbers of pistillate florets per panicle, fruit dry weight, proportions of mature, moderatley mature, immature, undeveloped and predated fruit, and stand areas and open areas. The variance of each variable and its contribution to the amount of fruit available for harvest is described and discussed. The low proportion of fruit harvested was attributed to harvest effort and machinery inefficiency. Predation by riceworm larvae was substantial at some stands in some years. Significant variation in stem density and floret number amongst and within stands was attributed to both genotype and habitat.

Genotypic variation in floret number and fruit dry weight amongst populations was demonstrated by growing plants from six sources under the same conditions at four water depths. Plants from some sources produced more florets and/or larger fruit than others at some or all depths. A trend towards larger but fewer fruit at greater water depths was demonstrated. The response to water depth varied with the source. It was concluded that more gain was to be made by

selecting superior plants than collecting seed from superior stands without selection.

The ranges and dynamics of selected water and sediment physical and chemical parameters were described. These were evaluated on their ability to discriminate littoral sites if data were collected on a one-time survey basis. Sediment characteristics, in particular loss-on-ignition and sediment micro-nutrients, were considered the most useful variables.

Models were developed to predict and identify the causes of Z. palustris plant survival and plant performance in terms of biomass, tiller number and floret number. Sediment phosphate concentration was the most important variable and sediment minor nutrients were persistently indicated for inclusion in the models.

This study provides the first documentation of Z. palustris plant failure. The failures were attributed to a lack of plant nutrients in highly organic littoral sediments.

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Gerald Blaha, Minnesota Pollution Control Agency, St. Paul, MN 3/20/13

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GENERAL INTRODUCTION

The research reported herein was conducted in response to requests by wildrice harvesters wishing to improve fruit production from natural stands of wildrice (Zizania palustris L.) and to introduce the plant into suitable water bodies in eastern Ontario. A review of available information revealed that no quantitative description of fruit production in natural stands was available with which to compare and evaluate stands, nor had the specific requirements of the plant been reported. Some generalities had been described (Moyle, 1944, 1945, Rogosin, 1954, Dore, 1969), but few habitat characteristics had been quantified except by Lee (1979, 1981, 1982, 1983, 1984) and relationships of habitat characteristics with fruit production had not been undertaken.

The broad objectives of the research were to:

1. quantitatively describe the fruit production variables of natural stands of wildrice in eastern Ontario and assess existing populations in terms of their harvestable fruit production;
2. demonstrate the influence on fruit production of genotypic variation between stands;

3. identify the habitat characteristics most influencing wildrice fruit production and as determined in a one-time, regional survey.

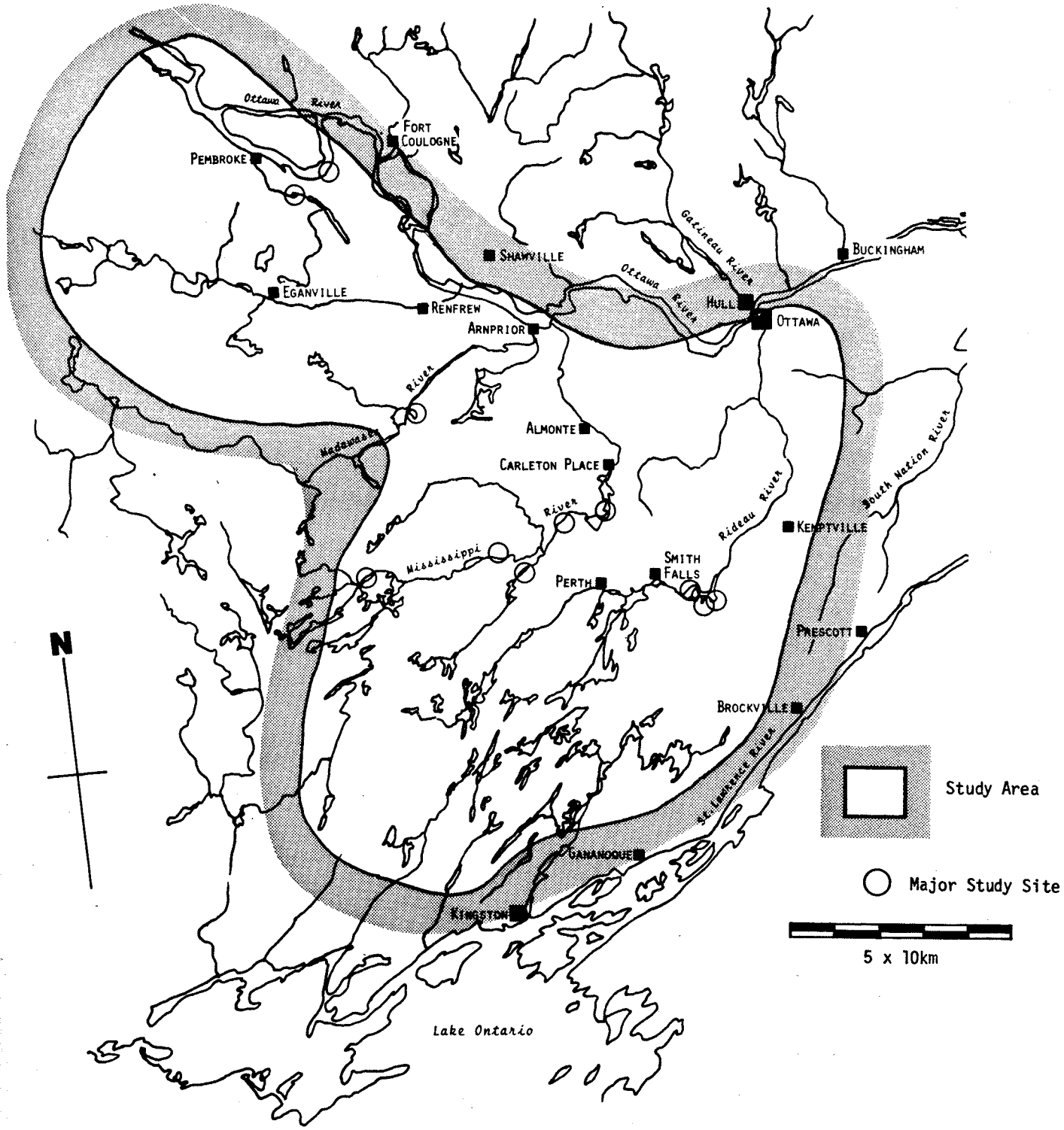
1.1 STUDY AREA

The surveyed area is illustrated in Figure 1. It is bordered on the north by the Ottawa River and on the south by the St. Lawrence River. A line between Kingston and Pembroke roughly delineates the western boundary.

The physiography of the region was most influenced by the Champlain Sea (Chapman & Putnam, 1966) formed during the recession of the Wisconsin glaciation. Deposits of limestone, sandstone, marine clays, lacustrine clays and eroded morainic gravel are scattered throughout the region of the Ottawa and St. Lawrence valleys. The western part of the region rises onto the precambrian shield.

Four major river systems drain the region, the Nation, Rideau, Mississippi and Madawaska (from east to west respectively), all flowing north-eastward into the Ottawa River. Their headwaters are on the precambrian shield. Bordering the shield are a number of shallow lakes, often surrounded by cultivated fields. The rivers flow through the limestone and clay plains near the Ottawa river where farmland dominates.

Figure 1: Study Area



Wildrice is found scattered throughout the region (Dore, 1969) in the rivers, lakes and creeks. Some extensive stands exist which are harvested commercially.

The region has a continental climate with relatively large seasonal and daily temperature variations. Extremes of -40°C and 38°C have been recorded in January and July respectively. Mean monthly temperatures for these months are -16°C and 27°C. An average of 142 frost free days occur typically between May 11 and Oct 1 at Ottawa. The growing season (days >5°C) is 195 days with an average of 2089 degree days. Total precipitation averages about 840mm with most rain occurring in August and September. Prevailing winds are from the WNW, but during the summer the greatest winds come from the SSW. The least winds occur during July and August.

1.2 LITERATURE REVIEW

The plants asssociated with Zizania palustris in the lower Ottawa River and some measure of the degree of association are given by Vincent and Bergeron (1983). Tessier et al. (1981) give degrees of association within Zizania communities in the St. Lawrence River. The list of associates given by Lee (1979) for a Minnesota site is similar to that encountered in the study area except for Fontinalis duriaei Schimp. and Ranunculus longirostris Godr.. Crowder et al. (1977) describe the vegetation of sixteen lakes within or

near the study area. They identified 50 species, most of which were identified in the area during this study.

The habitat requirements of Zizania spp. have not been empirically determined. Observations have been made of natural wildrice stands and some habitat parameters associated with the sites have been recorded, although not in detail, by Moyle (1944, 1945) and Chambliss (1940). Moyle (1945) published the results of a survey of 225 water bodies in Minnesota, of which 43 contained Zizania. Measurements of water pH, total alkalinity and sulphate were given. He also observed that the nature of the sediment and the water body affected local distribution. No attempt was made to test for any correlations or identify the controlling parameters. Rogosin (1954) summarized the habitat conditions associated with Z. aquatica and Z. palustris which were published to that time and conducted some experiments on water depth and fertility (Rogosin, 1957). Dore (1969) summarized and discussed the general information concerning habitat for Zizania. Thomas and Stewart (1969) investigated water depth and Weber and Simpson (1967) identified a need for the soil to be flooded or near saturation for wildrice to survive. Lee (1979, 1981, 1982, 1983, 1984) did more detailed sampling and analyses at some sites in northwestern Ontario and in Minnesota. Some investigation into conditions associated with successful and unsuccessful establishment of wildrice stands were conducted by Payne (1979) in Nova Scotia. Rang-

es of some variables may be gleaned from papers on aquatic macrophyte communities in general, such as Vincent and Bergeron (1983). Recent work by Lee (1984) and Atkins (1983) in northwestern Ontario is furthering our description of water and sediment parameters and relating them to wildrice biomass and density. A great deal of agronomic and some physiological work has been conducted by Oelke (1974-1983) and Oelke et al (1973) but this has been directed towards optimizing yields from paddies. Oelke and Albrecht (1978, 1980) and Grava and Raisanen (1978) have studied some physiological aspects. Ogan (1977) reported nitrogen fixation related to wildrice in its habitat. Lee (1979, 1981, 1982, 1983, 1984) has been most active in gathering habitat data and correlating it to wildrice development.

Chapter I

FRUIT PRODUCTION OF WILDRICE (Z. PALUSTRIS L.) NATURAL STANDS

1.1 INTRODUCTION

Northern Wildrice (Zizania palustris L.) has long been harvested from natural stands occurring in sheltered waters of lakes and rivers in North America (Lloyd, 1939; Chambliss, 1940; Dore, 1969). The total harvesting effort has grown steadily with the market for the product. Harvesters and managers have been trying to optimize the yield from such stands and have relied upon subjective, visual analysis of stands and measurements of grain harvested to evaluate stand potential (Stack, 1967--1977, Lafferty and Bailey, 1980).

Comparisons of the genetic capabilities and fruit production capacities of wild rice in natural stands have not been published. A few measurements of seed length and diameter of Z. aquatica and Z. palustris were given by Brown and Scofield (1903). Measurements of plant density, number of tillers, florets per panicle and grain size and weight of Zizania plants grown in paddy culture may be gleaned from research reports from the Minnesota Agricultural Experimental Station (1973--1983). It cannot be assumed that these

measurements represent the ranges to be found in natural stands.

Only one study of the success of pollination and survivorship of fruits to maturity was available. This was conducted by Lafferty and Bailey (1980) on Kabinakagami Lake in northwestern Ontario.

The work described in this chapter was undertaken to provide representative data for the comparison and evaluation of stands and individual plants of wildrice growing in natural water bodies in eastern Ontario, and to demonstrate the most limiting fruit production characteristics. Some comparisons were made between quantities of fruit available for harvest and those actually harvested.

For the purposes of this study the basic unit harvested is termed the fruit, this being the caryopsis (commonly referred to as 'grain') together with its adhering floral parts (palea and lemma, or hull). It may be referred to as green - the condition as collected from the plant - or as dry, having been dried to constant weight in an oven. The term 'processed grain' refers to the grain after curing, parching and dehulling.

1.2 METHODS

1.2.1 Study Sites

A survey of eight stands in six water bodies was conducted during the 1980 season. Five of those stands in five water bodies were again sampled during the 1981 season. Other sites were sampled for some parameters during 1980-82 (Figure 2).

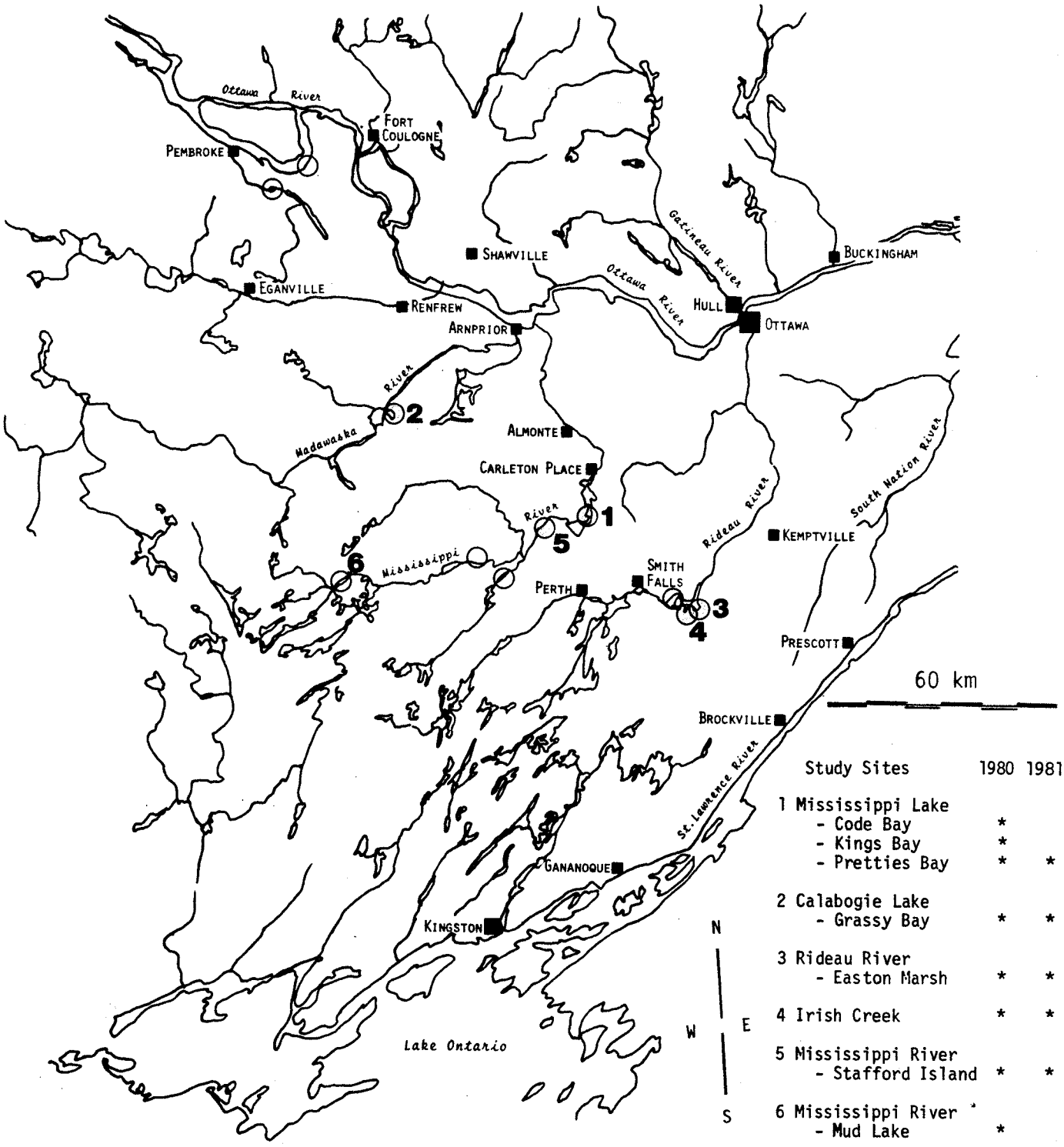
1.2.2 Plant Sampling

Sites which were sampled intensively during the 1980 and 1981 seasons, were visited between the times of pollen dispersal and fruit maturation. Varying numbers of stations were subjectively chosen so that the ranges of variation in plant and fruit production characteristics could be sampled.

Data collected included the density of Zizania stems and panicles, the number of pistillate florets per panicle and the numbers of fully developed, moderately developed, poorly developed, undeveloped and predated grains recovered from bagged panicles.

The densities of stems and panicles at each station were sampled by four $0.25m^2$ quadrats constructed by placing wooden laths between the plants. Care was taken to prevent the canoe from pushing the plants together. Stems emerging from the water within the quadrat were counted. Also recorded were the number of stems which had been clipped by animals

Figure 2: Wildrice Stands Sampled for Fruit Production - 1980-1981



at the water level. The number of panicles fully or partially emerged from their sheaths were counted.

Ten panicles were bagged at each station. Efforts were made to avoid bias in their selection by blindly reaching out and grasping a stem which was then checked for completion of pollination as indicated by the absence of stigmas. The selected panicles were covered carefully with a treated paper pollination bag of a size specifically designed for wildrice. The open, bottom end was folded and stapled to prevent the loss of fruit. The stems would not support the weight of the bags, so the selected stems were carefully gathered with other stems and tied to a post. After the fruit had matured, the bagged panicles were recovered by clipping the stem below the bag. Additional panicles were collected so that the number of panicles from each station was twenty.

The number of pistillate floret scars on each of the collected panicles was counted. The fruit retained in the bags were separated into categories of fully mature, moderately mature (of commercial value), poorly developed (not of commercial value), undeveloped and fruit predated by larvae of Apamea apamiformis (Guenee). The number of fruit in each category from each panicle was recorded.

The fruit in the fully or moderately mature categories were dried to constant weight at 95°c, stored under vacuum in the presence of a dessicant and weighed, either as a sta-

tion lot for the 1980 sampling season, or individually for the 1981 sampling season.

The relationship between dry and green fruit weight was determined by drying seven batches of green fruit harvested from various stands constant weight at 85°C.

1.2.3 Stand Areas

The sites were overflown and photographed when the wildrice plants were emergent. Areas of homogenous wildrice density were identified from the photographs and delineated on technical aerial photographs (source: Ontario Ministry of Natural Resources). Each area was measured by means of a planimeter and classified as dense or thin.

The proportion of each area which was devoid of wildrice was estimated subjectively from aerial photographs and used to estimate the net area (ie. net area = gross area x (1 - proportion open)). The data for each sampling station were used to represent one or more of the corresponding delineated areas. Fruit production was estimated for each area and for the entire stand.

During 1980 six of the sampled stands were harvested commercially using airboats equipped with "speed heads" (trays for collecting wildrice). On each day of the harvest a single pass was made in a systematic pattern to cover the entire stand. This was repeated every three days until the

harvesters considered the returns to be not worth the effort. Each bag of green fruit harvested from each source was weighed. These data were compared with calculated estimates of wildrice available for harvest.

1.3 RESULTS

Many bags and/or plants were damaged by weather conditions and birds. A recovery rate of fifty percent of intact bags was good. Usually entire stations were lost.

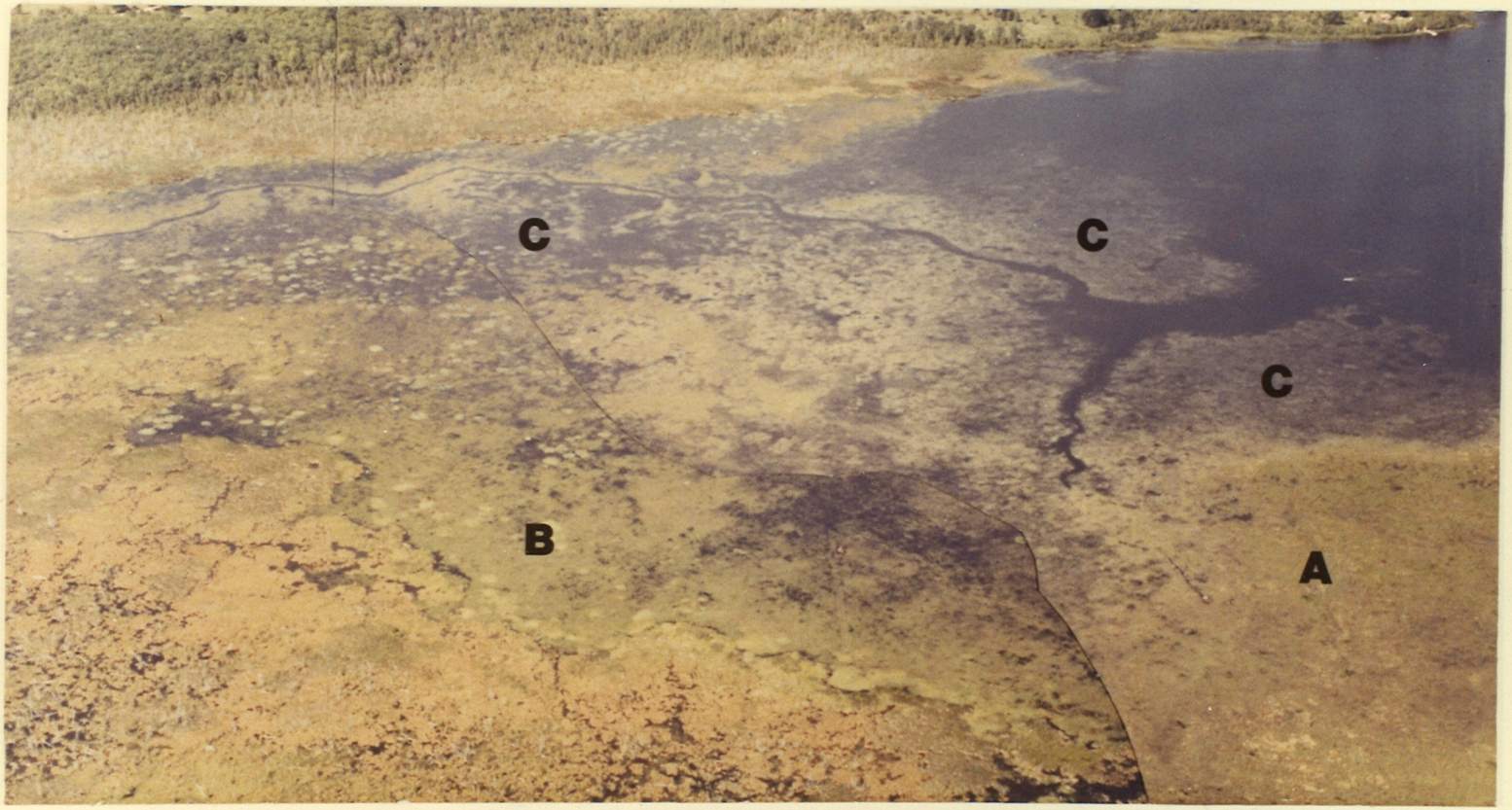
1.3.1 Fruit Production Characteristics

1.3.1.1 Stem and Panicle Density

The density of stems varied considerably within stands. (Figure 3). Deep water extremities of stands had scattered plants, very often clipped by animals. The densest, most robust plants were along the margins of areas, particularly bordering channels such as at Calabogie Lake (Figure 4). The interiors of stands often had very low stem densities. At some locations robust plants grew in high density and matured early. These often became uprooted after high winds. Other areas of the stands which did not grow so rapidly were not subject to such losses.

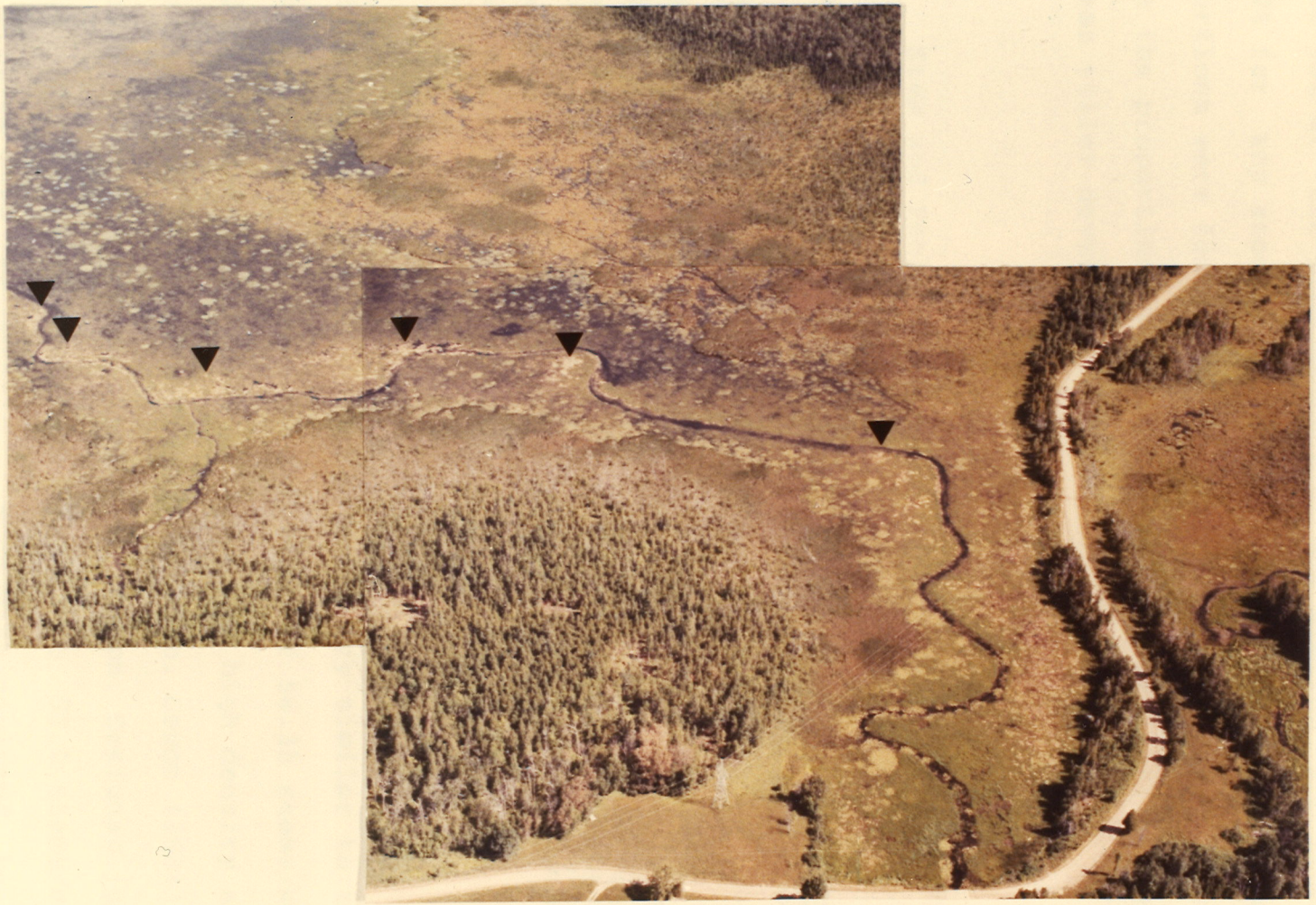
Table 1 gives representative values for stem and panicle densities at each stand. Stem densities ranged from 4 to 285 stems/m^2 at individual stations and from 89 to 165 stems/m^2

Figure 3: Wildrice Stand - Grassy Bay, Calabogie Lake - July, 1981



Note dense areas A and B, and thin area C.

Figure 4: Aerial Photograph - Stoughton Creek, Calabogie Lake - July, 1981



Note higher density of wildrice bordering the channel and uprooted wildrice ▼.

for the sampled stands. The density of panicles ranged from 25% to 96% of the stem density at any station and from 44% to 82% for any stand, the median being 66%. The highest proportions were found at Pretties Bay and Stafford Island where the proportion of primary stems was greater, a result of less tiller development.

TABLE 1

Stem and Panicle Densities of Wildrice Stands

Site	Year	Stem Density (stems/m2)	Panicle Density (stems/m2)	Predated Stem Density (stems/m2)
Code Bay - Mississippi Lake	80	72.3	42.5	28.0
Grassy Bay - Calabogie Lake	80	91.3	60.6	1.7
	81	165.5	136.0	3.5
Easton Marsh - Rideau River	80	91.8	40.4	-
	81	88.9	61.7	6.6
Irish Creek - Rideau River	80	94.6	63.2	-
	81	93.3	53.5	6.8
Kings Bay - Mississippi Lake	80	78.0	36.5	26.0
Pretties Bay - Mississippi Lake	80	112.5	79.8	27.5
	81	117.2	93.5	27.5
Stafford Island - Mississippi R.	81	176.3	134.6	-

Note: values are means of station means

The stem densities encountered were very similar to those reported by Lafferty and Bailey (1980) of 56.35 stems/m^2 in low density areas and 123.50 stems/m^2 in high density areas of Kabinakagami Lake, northwestern Ontario. Count (1984) reported 8 to 66 stems/m^2 in that same region. Cesiunas (pers. comm.) reports stem densities of 32.5 to 97.0 stems/m^2 in the Timmins area of Ontario. None distinguished between stems bearing panicles and stems not yet bearing panicles. Lee (1979) reports panicle densities of 44 to 150/m^2 (mean

83 panicles/m^2) from natural stands in Minnesota and densities of 59 to 250 panicles/m^2 in Ontario.

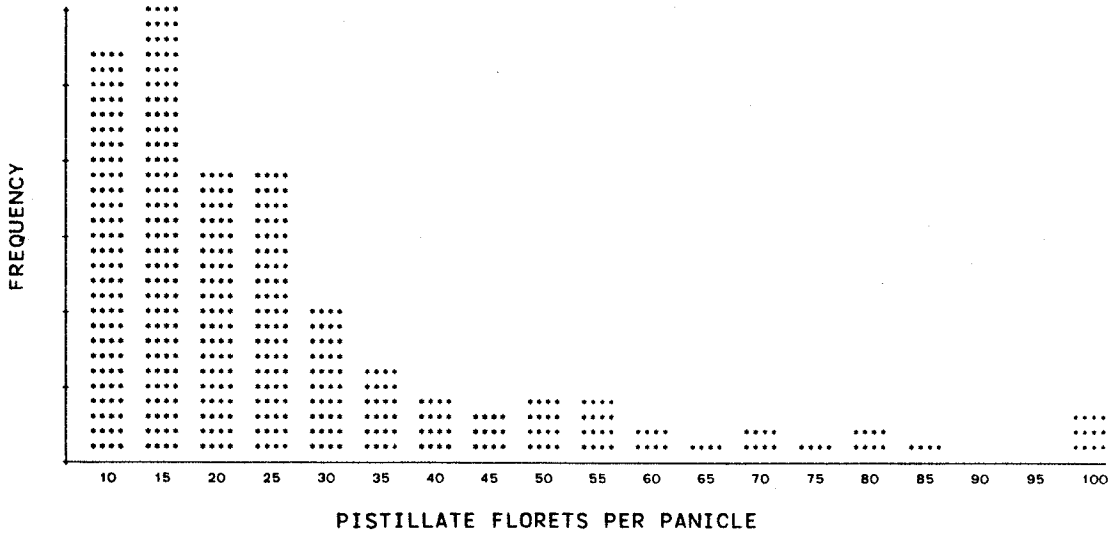
Lee (1979, 1983) and Atkins (1983) give examples of seasonal variations in plant densities ranging from 110 to 350 plants/m^2. However, corresponding values for number of tillers were not recorded so that stem densities and thus production estimates cannot be derived. These examples show varying patterns of survival at the various sites. Those of Atkins illustrate the loss of plants corresponding with a rise in water level.

The densities described range broadly but remain comparable to the density of 40 plants/m^2 or 81 to 145 stems/m^2 suggested by Oelke (1974, 1975) as being optimal in Minnesota paddies.

1.3.1.2 Floret Number

Individual inflorescences bore from 4 to 163 pistillate florets (Figure 5) and stand means ranged from 13 to 71 florets per panicle (Table 2). It was observed that the minimal number was typically around 10 at sites where the plants barely survived. The variance of the number of florets increased with the mean so Taylor's Power Law was used to determine a suitable transformation to reduce this dependency ($z=x^{-.081}$). A Waller-Duncan T test of the means of the transformed data was used (SAS - PROC GLM) to identify significantly different groups (Table 2).

Figure 5: Distribution of Florets per Panicle



NOTE: counts are weighted by the inverse of the stand relative frequency (total frequency / stand frequency)

Lafferty and Bailey (1980) recorded means of 12.3 and 16.4 florets per head in northwestern Ontario. Lee (1979) reports a skewed distribution of fruit number (mean=40; range 11-120) in northeastern Minnesota and northwestern Ontario, similar to that in this study. He reports that 75% of the panicles had less than 50 seeds compared with Moyle's (1945) report of 34% with less than 50 seeds. In this study, ten of the twelve stands sampled had mean numbers of florets per panicle less than 50. Lee attributes the lower floret

TABLE 2

Number of Pistillate Florets per Panicle - Waller-Duncan T Test

group	mean	n	site - year
A	71.2	19	Rosedale Creek - Rideau River
A			
A	62.9	102	Bellows Bay - Ottawa River
B	37.9	20	Muskrat Mud Lake - Muskrat River
B			
B	36.5	25	Irish Creek 1980 - Rideau River
B			
B C	29.3	35	Easton Marsh 1980 - Rideau River
C			
C	26.0	177	Easton Marsh 1981 - Rideau River
D C			
D E C	24.3	29	Grassy Bay 1980 - Calabogie Lake
D E			
F D E	22.7	107	Irish Creek 1981 - Rideau River
F D E			
F D E G	22.2	270	Grassy Bay 1981 - Calabogie Lake
F E G			
F H E G	20.6	15	Ottawa River - Bonnechere River
F H G			
F H I G	19.3	59	Stafford Island 1980 - Mississippi R.
F H I G			
F H I G	17.7	6	Code Bay - Mississippi Lake
H I G			
H I G	19.5	233	Grassy Bay transect A - Calabogie Lake
H I			
K H I	15.8	13	Kings Bay - Mississippi Lake
K I			
K I L	15.0	5	Stafford Island 1981 - Mississippi R.
K L			
K M L	14.2	19	Mud Lake - Ardoch - Mississippi R.
K M L			
K M L	13.3	29	Prettie Bay 1980 - Mississippi Lake
M L			
M L	13.1	14	Prettie Bay 1981 - Mississippi Lake
M			
M	11.6	207	Grassy Bay transect B - Calabogie Lake

Means with the same letter are not significantly different
This test minimizes the Bayes risk under additive loss and certain other assumptions (SAS 1982).

number to sample bias introduced by different geographic areas (lower floret numbers in N.W. Ontario than in Minnesota). This appears to be a reasonable conclusion since Z. palustris var. interior (Fassett) Dore, which produces more florets per panicle, was observed to be more prevalent in Minnesota than the variety palustris Hitch. which is the dominant variety in Ontario (Dore, 1968).

Within most stands the mean number of florets produced was found to vary with the year. Only at Pretties Bay, the poorest of sites, was the difference in yearly means insignificant at the 5% level.

The means between stations within a site were significantly different as determined by a Waller-Duncan T-test of means of transformed data ($z=x^{-.09}$). The results for one transect of Calabogie Lake, the most typical, large, commercially producing stand in the study area, are given in Table 3 as an example. The interval between the stations was only 20m.

1.3.1.3 Pollination

The degree of pollination was represented by the proportion of developed or developing grains collected from the bagged panicles. The proportions of developed or undeveloped fruit for each head were calculated and the mean of these used to represent the station. This was done to offset the effect of the method of collection from stations within stands and the inconsistent number of panicles recovered from each station. This precluded any statistical analysis of the results based upon assumptions of randomness and equality of variance.

Table 4 shows the representative mean values for the stands which were best sampled over the two years. The mean

TABLE 3

Number of Pistillate Florets per Panicle - Calabogie Lake Stations - 1982

grouping	mean florets per panicle	n	station number
A	35.368	19	6
B	28.647	17	5
B C	26.250	20	8
C D	23.900	20	9
D E	20.600	20	11
D E	20.200	20	7
E	18.389	18	1
E	16.700	20	4
E	16.650	20	10
F	10.895	19	0
F	9.476	21	3
F	8.368	19	2

Means with the same letter are not significantly different

This test minimizes the Bayes risk under additive loss and certain other assumptions.(SAS, 1982)

Kratio=100 df=221 mse=51.3861 F=24.329
critical value of T=1.77141
minimum significant difference=4.08154

pollination rate was 84% with little variation, the minimum being 75%. Some differences were evident between years.

The same assumption of undeveloped fruit representing unpollinated florets was used to compare the results of Lafferty and Bailey (1980). They indicated 93% and 91% pollination.

TABLE 4

Pollination Rate of Wildrice Stands - 1980, 1981

stand	year	pollination rate 1	number of stations
Calabogie	80	.890	10
Lake	81	.841	29
Easton	80	.914	10
Marsh	81	.899	15
Irish	80	.754	12
Creek	81	.844	18
Pretties	80	.784	05
Bay	81	.818	11
Stafford	80	nd	nd
Island	81	.828	22

Notes - 1 - pollination rate is taken as 1-proportion undeveloped seed
- nd - no data available

1.3.1.4 Fruit Development

To the harvester, any fruit which does not develop to a reasonable size is of no value. Thus the totals of only the mature and moderately mature fruit were taken to represent the commercially useful portion.

The proportion for each plant and means for each station were used to represent each station so they would be equally weighted. Table 5 gives the means for each stand. Most stands had high proportions of commercially useful fruit at the time of harvest (69%-85%). Three stands, Easton Marsh, 1981, Irish Creek, 1981 and Pretties Bay, 1980, showed a high proportion of poorly developed fruit (10.4%, 11.9%, 18.5% respectively). The low proportion of useful fruit at Irish Creek in 1981 was attributed to a high rate of Apamea predation (30%), late development (12%) and heavy blackbird

predation. The low values for Pretties Bay, 1980, could be, in part, influenced by low sample number (5 stations). Excluding these two records, the mean proportion of fruit development at time of harvest was 76% (n=7; st. dev=5.6%).

Lafferty and Bailey (1980) indicated somewhat higher proportions of mature and immature fruits (89.5% and 91.9%) but they do not differentiate between moderately well developed and poorly developed grains as was done in this study.

TABLE 5

Proportion of Commercially Useful Wildrice Fruit

Stand	Year	Proportion Useful Fruit
Calabogie Lake	1980	.778
	1981	.767
Easton Marsh	1980	.845
	1981	.772
Irish Creek	1980	.687
	1981	.386
Pretties Bay	1980	.456
	1981	.686
Stafford Island	1980	nd
	1981	.783

Notes - - proportion of useful fruit includes both fully mature and moderately mature mature fruit
nd - no data

1.3.1.5 Predation and Disease

The loss of fruit due to predation and disease is a final factor influencing fruit development. Major losses are frequently caused by blackbirds (Agelaius phoeniceus), riceworm (Apamea apamiformis) larvae and ergot (Claviceps zizaniae

Fyles). Blackbird damage was observed to be locally extreme, but not readily quantifiable. Estimates of greater than 70% loss due to blackbirds in paddies have been documented (Moulton, 1979). No measure of this loss was included in this study.

The losses due to Apamea were estimated by the proportion of grain damaged by the larvae as taken from the bagged heads. The degree of predation by Apamea larvae ranged from 1% to 30% with most stands maintaining less than 10% (Table 6). Lafferty and Bailey (1980) indicated 1.7% and 0.9% of the hulls damaged by riceworm. The Irish Creek stand suffered very low predation in 1980 (<1%) and very high predation in 1981 (30%).

TABLE 6

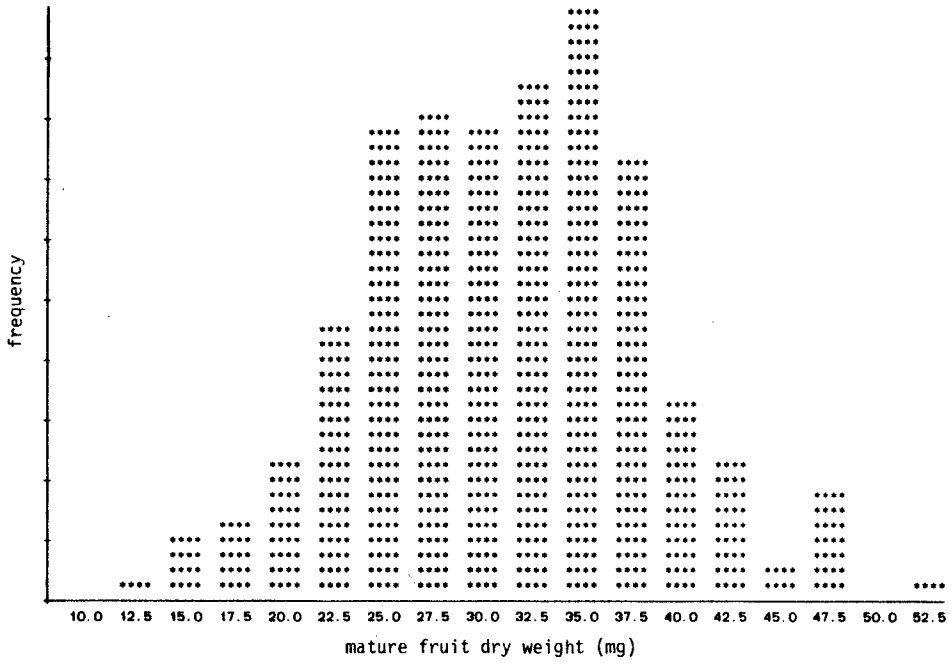
Proportion of Fruit Predated by Riceworm Larvae

Site	Year	Proportion Predated Seed
Calabogie Lake	1980	.039
	1981	.013
Easton Marsh	1980	.001
	1981	.058
Irish Creek	1980	.005
	1981	.300
Pretties Bay	1980	.072
	1981	.093
Staffford Island	1980	nd
	1981	.038

Note - nd-no data available

Ergot was never found on any plant in the region, thus it is not a factor in this study.

Figure 6: Distribution of Fruit Dry Weight



1.3.1.6 Fruit Weight

The dry weight of mature fruit collected from bagged panicles in 1981 ranged from a panicle average of 13mg to 51mg per fruit (mean 31.2mg; n=249; st.dev.=4.96mg) (Figure 6). The distribution for each stand was approximately normal. Lafferty and Bailey (1980) reported mean grain dry weight of 22.50mg (green weights - 35.75mg, 35.0mg) from Kabinakagami L., northwestern Ontario.

Significant differences between stands were identified by a Waller-Duncan T-test (Table 7).

TABLE 7

Developed Fruit Dry Weight - Waller-Duncan T Test

Group	Mean Fruit Dry Weight (mg/fruit)	n	Site
A	33.96	120	Grassy Bay - Calabogie Lake
B	31.19	55	Easton Marsh - Rideau River
B			
B	30.40	22	Pretties Bay - Mississippi Lake
C	27.49	8	Stafford Island - Mississippi River
C			
C	24.89	44	Irish Creek - Rideau River

Means with the same letter are not significantly different

This test minimizes the Bayes risk under additive loss and certain other assumptions (SAS, 1982)
Kratio=100 df=191 mse=24.55 F=22.67 Critical value of T=1.775
Minimum significant difference=2.608
Harmonic mean of cell sizes=22.759

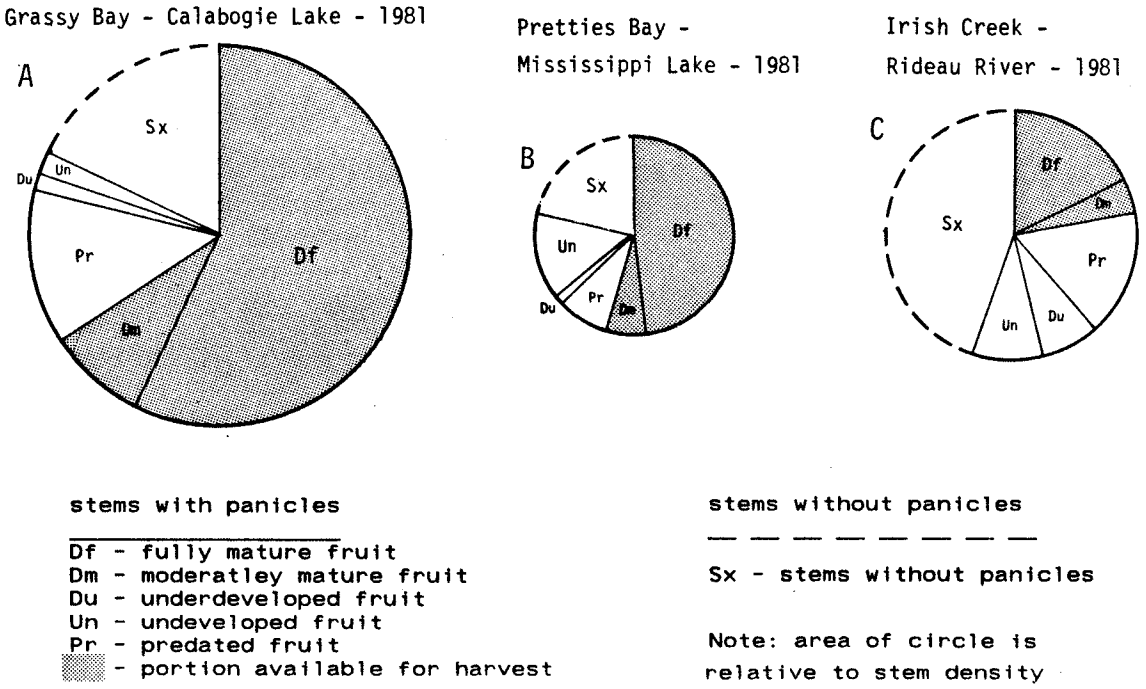
1.3.2 Stand Fruit Production

The fruit production of interest to harvesters (mass of fruit available for harvest) was estimated for each stand or stand subarea as the product of fruit numbers per unit area, fruit weight, and net area at the time of harvest.

Examples of estimates of production (in terms of numbers of fruit) are given in Figure 7. These illustrate good, poor and heavily predated stands (A, B and C respectively). The areas of the circles represent the estimated unit area fruit productions (the product of stem densities and floret numbers). These are partitioned to include a section representing the proportion of stems bearing panicles (44% to 82%

of the stems; mean 67%) and this is further partitioned according to the development and survival of the fruits. The portions indicating fully mature and moderately mature fruit are those available to the harvester. These range from 22% to 64% (mean 33%) of the absolute potential number. The sites with low proportions of mature fruit had high degrees of predation by Apamea. The stems without panicles (Sx) may develop fruit, but these would not be available for harvest due to their late development.

Figure 7: Proportions of Commercially Useful and Predated Wildrice Fruit and Stems - 1981



The mass of commercially useful fruit produced per unit area (Table 8) provides a comparison of stand production. This was calculated using the equation:

$$fl \times hd \times((dev \times wtdev) + (mdev \times wtmdev))$$

fl - florets/panicle hd - panicle/m^2
dev - prop. grain fully mature
mdev - prop. grain moderately mature
wtdev - dry weight mature grain
wtmdev - dry weight moderately mature grain

Two methods of calculating the production were used, the first using the mean value of each variable in the equation for each stand. The second method takes into account the varying proportions of high and low density subareas in each stand by calculating the production for each subarea and dividing the total for all subareas by the gross area of the stand. Some of the estimates differ considerably by the two estimates (eg: Easton Marsh 1980; Grassy Bay 1980) but most are similar. Considerable differences in production between years were found. The range of 25 kg/ha to 676 kg/ha is broad, indicating a wide diversity of stand production. The stands with low estimates (<100 kg/ha) had high incidences of Apamea predation and either low density or low fruit weight.

Lafferty and Bailey (1980) derived similar estimates, although their methods were less thorough. They estimated fruit production at 125 kg/ha dry weight in low density areas and 385.2 kg/ha dry weight in high density areas of one lake.

TABLE 8

Estimates of Unit Area Wildrice Fruit Production

Site	Year	Estimated 3 Seed Production (Kg/ha)	Estimated 4 Seed Production (Kg/ha)
Code Bay - Mississippi Lake	80	25	-
Kings Bay - Mississippi L.	80	36 1	89
Pretties Bay - Mississippi L.	80	103	149
	81	213	224
Irish Creek - Rideau River	80	249	431
	81	64 2	137
Easton Marsh - Rideau River	80	121	336
	81	217	143
Grassy Bay - Calabogie Lake	80	281	410
	81	675	676
Stafford Is. - Mississippi R.	81	309	300

Notes: - 1- high predation, low density
2- low fruit weight and high predation
3- estimate based on stand mean value (see text)
4- estimate based upon differential densities of stand subareas the total production divided by the gross area of the stand

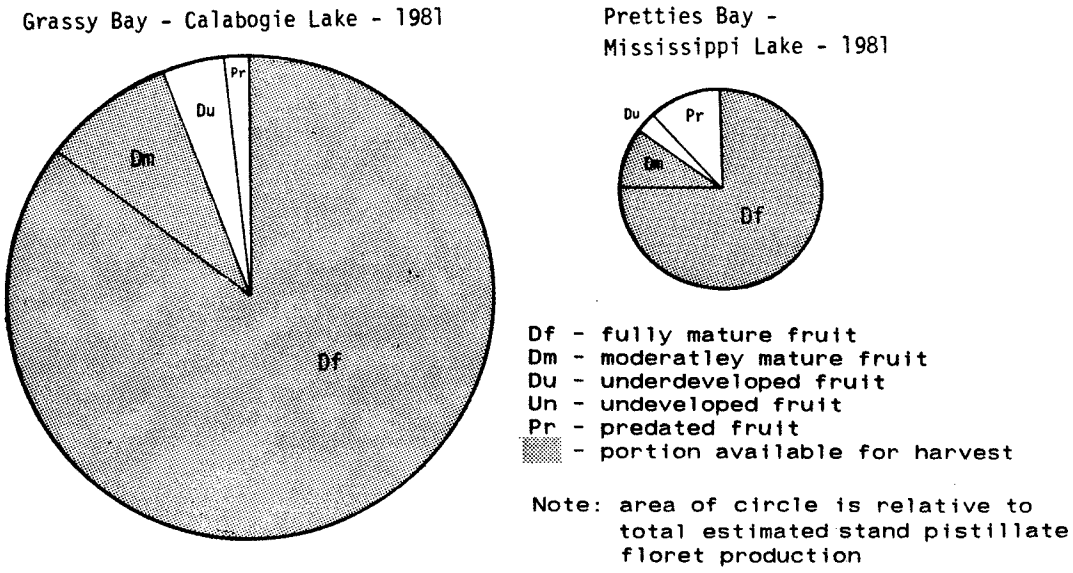
1.3.2.1 Stand Area

The final factor involved in the evaluation of the stands is their area. As previously mentioned, within the limits of the stands are open areas, or areas so thinly populated by Z. palustris as to be considered open. These were subjectively estimated at from 10% to 90% of the area within the stand with the mean at about 44% of the stand area. These small, unmeasurable areas are not readily visible from with-

in the stand and are even less visible from on shore. Even when flying over the stand, their extent cannot be effectively appraised. The use of more or less vertical photographs and the evaluation of small areas within the stands gave a reasonable estimate.

The influence on total production of net area (gross area less open areas) is clearly of interest to the harvester. Figure 8 illustrates the difference in harvestable production potential (in terms of fruit number) between Pretties Bay and Calabogie Lake when the density of pollinated florets is multiplied by the net area.

Figure 8: Pollinated Floret Production of Two Stands - 1981



1.3.3 Harvested Fruit

The total fruit harvested from each stand in 1980 was compared with the estimates of total stand production (Table 9). Unfortunately, harvest efforts were inconsistent at most stands or were prematurely terminated due to land ownership anomalies at Calabogie Lake resulting in a harvest of less than 3% of the availabe fruit. Only at the Stafford Island stand did the harvest consist of at least four passes on a regular three day cycle. From that stand an estimated 19% of the available fruit was harvested.

The mean loss of moisture from the fruit upon drying was 36.3% (n=7, st. dev.=2.37%) of the green weight. Thus the dry weight of harvested wildrice was taken as 63% of the green weight.

TABLE 9

Comparison of Estimated Wildrice Available for Harvest and Actual Wildrice Harvested - 1980

Stand	Estimated Available Wildrice (kg dry wt.)	Actual Harvested Wildrice (kg dry wt.)*2	% Harvested
Mississippi L.	2 221 kg	249.5 kg	11%
Calabogie L.	16 528 kg	270.9 kg *1	2%
Easton Marsh	9 529 kg	300.5 kg	3%
Irish Creek	14 834 kg	178.3 kg	1%
Stafford Is.	2 166 kg	387.5 kg	19%

Notes -*1 - harvest stopped prematurely
*2 - measured as green weight - converted to dry weight (63%)

1.4 DISCUSSION

The fruit production capability of Zizania at any station is the product of several factors, including the stem density and the survivorship of the stems to fruiting.

Estimates of production may be based upon panicle density or stem density, but, if sampling is carried out approximately one week prior to harvest, the former will provide a better estimate of available harvestable grain. All panicles, whether barely emerged or nearly mature, were assumed to be available for harvest. A few mature fruit may shatter prior to harvest resulting in a slight overestimate; however, panicles still in the "boot" are unlikely to contribute to harvestable grain since pollination and maturation take at least two weeks (Rogosin, 1954) and harvest is usually completed within that time. Estimates based on stem density better reflect the overall stand fruit production, since late developing stems may continue to flower and fruit after harvest has ceased, although the pollination rate decreases. Some tillers not yet emerged above the water's surface at the time of sampling may reach maturity, offsetting the decreased pollination rate of late stems. Research to quantify the fruit production over the harvest period would test these assumptions and improve the estimation of production.

Areas with high stem density (max 285/m^2) are considerably over the maximum density of 145 stems/m^2 recommended for paddies by Oelke (1974, 1975). This suggests that such dense areas may require thinning to obtain optimal fruit production. The optimal density of natural stands needs to be studied.

The number of potential fruit is limited by the number of pistillate florets produced. No single "typical" quantity was taken to represent the number of florets produced. The wide range of stand means and even the wide range between stations within a stand illustrated the non-homogeneity of plant performance in the region and the influence of both genotypic and habitat variation.

Reasonable levels of pollination were indicated by both this study and by Lafferty and Bailey (1980). This variable may be responsible for some variation in fruit production between years, but was not considered of concern to producers.

The mass of individual fruits was comparable to those recorded by others in northwestern Ontario (Lafferty & Bailey, 1980; P. Sain, pers. comm.). The significant differences in fruit masses between stands indicated that some may be preferable to others if seed is to be collected for planting elsewhere.

The low proportion of fruit actually harvested was mostly a function of the harvest effort. However, even with a consistent harvest effort that proportion did not exceed 19%. This was attributed to the inefficiency of the machines commonly used to harvest natural stands which may blow the ripest fruit from the panicles before the harvester passes over them. The optimal frequency of harvesting passes has not yet been tested under experimental conditions. It is possible that harvesting on a one or two day cycle could yield a greater total harvest.

There is obviously a great potential for increased harvest yield by the development of more efficient machines for collecting wildrice from plants with the shattering habit. However, there is a limit over which the amount harvested will affect potential of the stand to regenerate itself. There is no indication at present as to what this equilibrium proportion might be. Extensive trials focussing on the survivorship of plants in natural stands would be required to determine the limit, but since the present methods of harvest appear to be so inefficient, there is no urgency for such studies.

The results indicated that predation of the developing fruit by Apamea larvae was responsible for a substantial reduction (30%) in commercially useful fruit at some stands. The significant difference in such predation between years is evidence that outbreaks of Apamea may be local and spo-

radic. Such a theory needs to be tested by monitoring the incidence of riceworm using sampling of larvae numbers and egg clusters.

The bagging of panicles had an unknown effect upon the predated fruit counts as they both trap larvae in the bag and protect them from predation as well as exclude larvae from panicles. Holes in the bags indicated that larvae would pass through the bag, or they could pass through the closure.

One concept of area, the harvestable area, was not estimated. Within many stands were areas so dense with wildrice plants, so shallow or containing so many obstacles such as stumps, that machine harvesting was impractical. Canoe harvesting could have taken place in some of these areas. The area remaining which could be harvested by whatever means chosen was termed the net harvestable area.

It was concluded that evaluations of stands must be by subareas. The stands surveyed were not homogeneous in plant density nor in floret production. The delineation of homogeneous subareas within stands and the estimation of net area of these subareas together with the establishment of specific sampling stations within each subarea was necessary to obtain reasonable confidence in the estimates of stand production available for harvest.

Estimates of stand fruit production suffer from the problem that any errors in sampling are multiplied in the calculations. For this reason many samples must be taken carefully to reduce the variance.

The major limitation to the amount of fruit harvested was the variation in the harvest effort and the relative inefficiency of the machines and harvest procedures commonly used. The most limiting biotic variables were the densities of stands and the numbers of florets produced per panicle. Both these variables varied considerably between stands. These may be limited by both the environmental conditions at each stand and the genotypic variation amongst stands (see Chapters II, III, IV). The other significant variable was predation by Apamea apamiformis larvae. The frequency of outbreak and the control of this predator in natural stands requires study.

Chapter II

GENETIC VARIATION OF FRUIT PRODUCTION CHARACTERISTICS OF WILDRICE

2.1 INTRODUCTION

Differences in the fruit production of Zizania plants are dependent upon the genetic capacities of the plants and the environmental conditions under which they are growing.

Some breeding trials have been conducted concerning various traits of Zizania including vegetative colour (Perlinger, 1976), shattering resistance (Perlinger, 1976, Woods and Clark, 1976; Elliott & Perlinger, 1977) and plant height, tiller number, heading date and seed length (Foster & Rutger, 1980). Breeding trials of floret number and seed mass have not been reported, but evaluation of plant lines and mass selection have been carried out in Minnesota paddies (Minn. Ag. Exp. Sta. 1973-83).

The genetic potential of the plants for fruit production cannot be correctly evaluated in the field because habitat conditions may vary greatly even over short distances (Lee, 1981, 1982) (see Chapters III & IV). In order to compare the capabilities of different populations of plants which are reproductively isolated, it is necessary to grow them in parallel under a range of environmental conditions.

The objectives of the trials reported in this chapter were to:

1. demonstrate genotypic differences between populations for floret number, fruit mass and time of flowering; and to document the extent of this variation;
2. demonstrate the influence of water depth on these production variables.

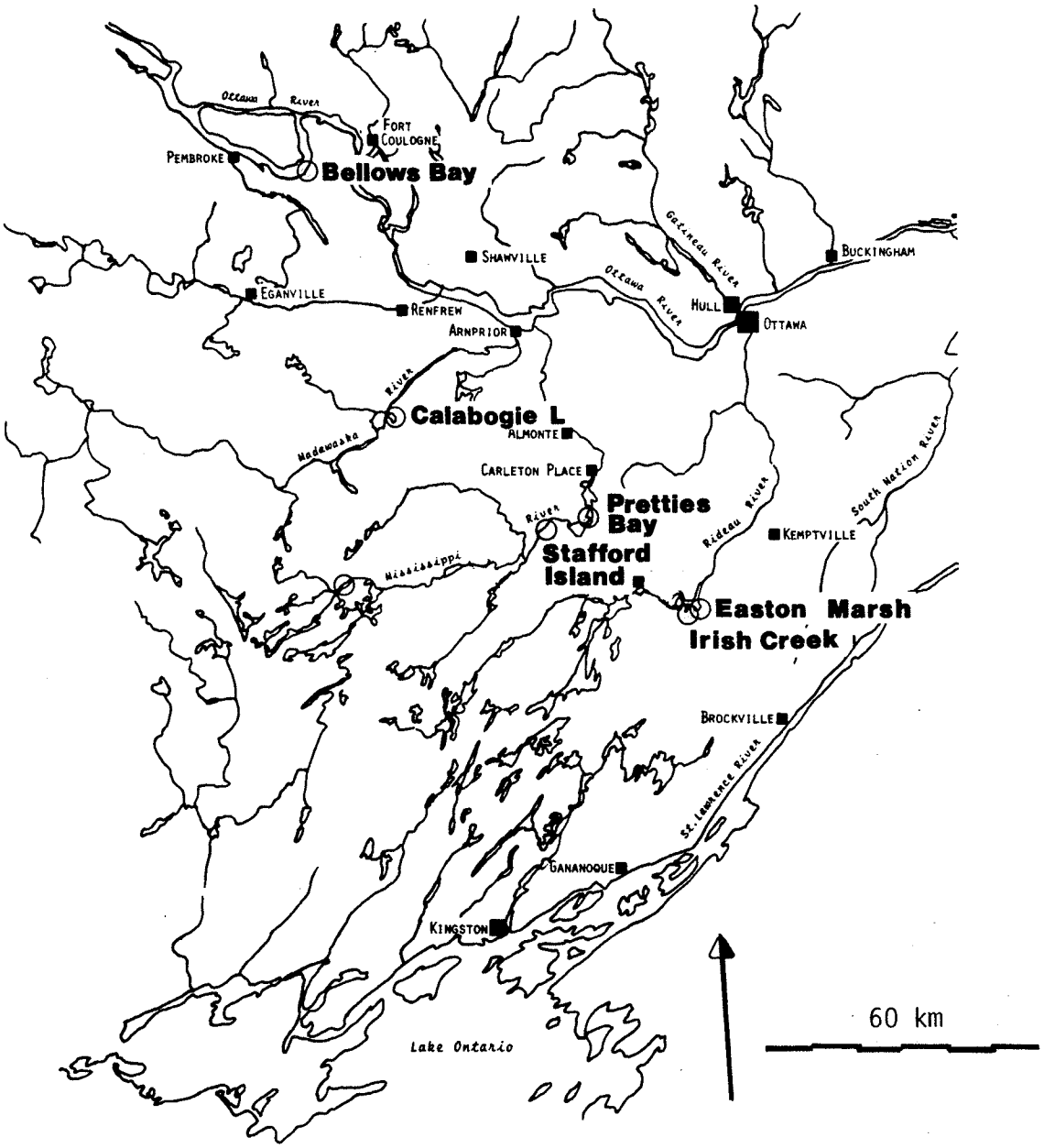
This was accomplished by growing plants from six sources in tanks in a greenhouse at four water depths.

2.2 METHODS

Wildrice seed was obtained from stands at (1) Irish Creek and (2) Easton Marsh on the Rideau River, (3) Pretties Bay on Mississippi Lake, and (4) Stafford Island on the Mississippi River during 1980 harvest; and from (5) Grassy Bay, Calabogie Lake on the Madawaska River and (6) Bellows Bay on the Ottawa River during 1981 harvest (Figure 9). The seed was stored in water in plastic bags at 3-5°C from September until February when they were germinated at room temperature.

Eight tanks measuring 610 x 610 x 910mm were constructed in the University of Manitoba Botany Department research greenhouse. They were made of plywood lined with polyethylene sheets and filled with water which was recirculated from a central tank.

Figure 9: Sources of Wildrice Seed used in Tank Trials



Four-litre plastic pails were partly filled with approximately three litres of potting soil (1/3 silica sand; 1/3 clay-loam; 1/3 peat) which had been used previously for growing Zizania. The pails were placed under water for several weeks prior to transplanting to encourage the development and stabilization of populations of microorganisms.

Germinated plants were transplanted to the pails, attempts being made to select plants of uniform age. Initially four plants from one source were transplanted into a pail and these were later thinned to two plants per pail. The rate of survival was almost 100%.

Two trials were conducted. In the 1981 trial two pails from each of four sources were randomly placed in each tank, and in the 1982 trial four pails from each of two sources were randomly placed in each tank. The pails were each marked with the source of the plants it contained. Supports were placed on the bottoms of the tanks so that the water depths over the soil were approximately 28, 43, 59 and 74cm in each of two tanks. Occasional failures of the water handling system caused rises in the water levels, but significant drawdowns did not occur. Water losses were made up with water from the City of Winnipeg water system. All tanks had similar insolation and temperature regimes.

2.2.1 Sampling

During 1981 each stem was marked at the time the panicle first emerged from the sheath with the date, an identification number and the source of the plant. emerged from the sheath. During 1982 this procedure was extended to identify both the plant and the tiller number.

The fruits from each panicle were collected, as they ripened, by gently tapping the panicle in a pail. They were dried at approximately 85°C for 24 hours (under 25mm mercury vacuum in 1982) and then cooled under vacuum in the presence of a dessicant before being weighed to 0.1mg.

The numbers of scars of the pistillate florets on each panicle were counted.

The data from these trials and statistics of the fruit numbers and fruit masses are included in Appendix C.

2.3 RESULTS

2.3.1 Floret Production

Significant differences in number of pistillate florets per panicle between seed sources at any one depth were identified using analysis of variance and Waller Duncan comparison of means (SAS proc GLM). However the ranks of the sources differed at different water depths. Figure 10 illustrates the confusion which arises in that no one source

was consistently superior at all water depths. Calabogie Lake and Bellows Bay strains produced more florets at the shallowest depth, but produced less at greater depths. The two sources remain significantly different from one another at all water depths. In contrast, the plants from Easton Marsh bore significantly more florets as the water depth increased ($r=.330$ $p>r=.0001$ $n=198$), suggesting an adaptation towards more fruit production in deeper water. The plants from Pretties Bay had consistently fewer florets than most sites except Calabogie Lake at most depths.

To illustrate the extent of variation of floret number amongst plants and between sources and depths, the standard deviation was partitioned (Table 10). The distributions of floret numbers for each source approached normality but were slightly skewed to the lower end.

TABLE 10

Partitioned Standard Deviation of Floret Number per Panicle

a	between plants	7.99 florets per panicle		- base standard deviation
b	between sources	2.47		- increase over a
b	between depths BE & CL	5.20		- increase over a
	IC,PB,EM,ST	0.49		- increase over a
	total standard deviation	10.70	(mean=25.56, n=1043)	

Note: the base and increases in standard deviations are the means for all units at the level, each with equal weighting (eg. mean std. dev. between plants is mean of deviations within source and water depth)

The mean standard deviation within sources of 7.99 florets per panicle was attributed to the genetic variation between the plants within populations and sampling variation.

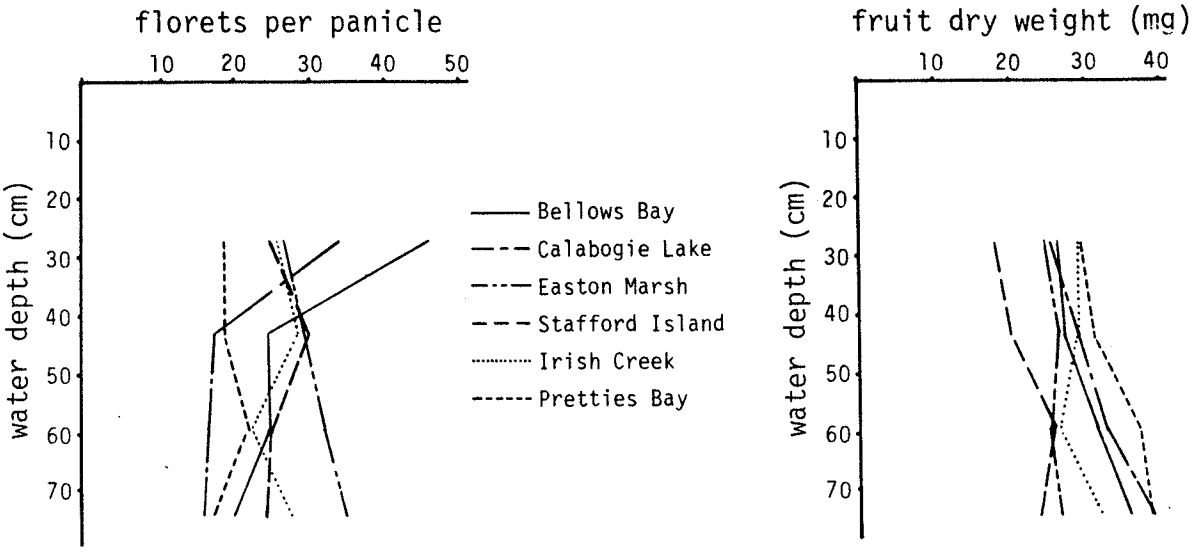
The increase in standard deviation between sources was only 2.47 florets per panicle (range 1.9 to 3.2, n=4), attributable to the difference amongst sources illustrated in Figure 10.

The effect of water depth differed between the two trials. In the second trial using plants from Bellows Bay and Calabogie Lake the standard deviation attributable to a depth response was 5.20 florets per panicle compared with a deviation of 0.49 florets per panicle obtained in the first trial with plants from the other sources. The large difference is a result of the Calabogie Lake and Bellows Bay strains responding to shallow water depth by producing a greater number of florets. (See Figure 10).

2.3.2 Fruit Dry Weight

No one source was consistently a better producer in terms of fruit weight than the others as the ranking varied with water depth (Figure 10). The plants from Stafford Island were consistently lower in fruit dry weight than plants from Bellows Bay, Calabogie Lake and Pretties Bay. The plants from Pretties Bay had one of the highest scores at all depths and the plants from Bellows Bay produced significantly more florets than those from Calabogie Lake at all depths.

Figure 10: Floret Number and Fruit Weight of Wildrice from Tanks



A trend towards greater fruit weight with increasing water depth was evident ($r=.224$ to $.996$, $p>r<.001$, $n>90$) (Figure 10). This tended to correspond with decreasing floret numbers.

The standard deviations of this variable were also partitioned. Samples of less than five fruits were dropped from the analysis. The distribution of fruit dry weight within each source was normal. The within tiller and within plant standard deviations were taken from the data collected in the second trial and the standard deviations for other levels were taken from data from all sources grown in both trials. Statistics were partitioned by depth or source when appropriate and mean standard deviations were calculated to avoid misrepresentation due to unequal sample sizes.

The proportion of total variation attributed to each level and expressed as standard deviation are given in Table 11. The base variation was attributed to differences in fruit development within panicles and sample variation. A very slight increase in deviation between tillers indicated some minor differences in development between tillers. Comparisons between main stems and subsequent tillers were found to be insignificant.

TABLE 11

Partitioned Standard Deviations of Fruit Dry Weight

a	within tiller	4.57 mg	- base standard deviation
b	between tiller	0.40 mg	- increase over a
c	between plants	2.20 mg	- increase over b
d	between sources	0.52 mg	- increase over c
d	between depths	0.63 mg	- increase over c

Note: the base and increases in standard deviations are the means for all units at the level, each with equal weighting (eg. mean std. dev. between plants is mean of deviations within cource and water depth)

The second largest variation was attributed to the genotypic variation between plants. This was greater than both the genotypic variation between sources and the variation attributed to water depth. The mean total deviation was of the order of 7.1mg to 8.1mg. Mean dry weight ranged from 18mg to 39mg.

2.3.3 Time of Flowering

Time of flowering varied by only several days amongst the sources. This was not considered significant within the methods used.

2.4 DISCUSSION

The results lead to the conclusion that population genotypic variation contributed to the variation in fruit number and size observed in the field. However, the considerable differences between the tank and field means for these variables (Table 12) also indicates a response to the environmental variation between source stands.

The results of the partitioning of variation illustrated that most gain in fruit size and floret number may be made by selecting superior plants rather than gathering seed from specific sites without plant selection. This does not rule out some gain to be made by selecting specific stands since the plants from some stands were found to produce more fruit than others. This was illustrated by the fact that plants from Bellows Bay produced more florets per panicle than those from Calabogie Lake, both in the field and in tank trials. However, if specific conditions of water depth are required, some sources may be more productive than others at shallow water depths.

The plants from Pretties Bay exhibited an adaptation for the production of larger but fewer fruits as compared with plants from other populations. Also a trend was observed for the production of larger but fewer fruits at greater water depths. Two sources which did not follow this trend were Easton Marsh and Irish Creek - adjacent stands (±1km apart)

on the Rideau River. This difference in response to depth was considered a population genotypic attribute which may be worth exploiting in certain cases.

The major limitation to such tests of genotypic variation between populations is that they are valid only for the conditions under which the plants are grown. Changes in a single parameter may lead to very different conclusions as illustrated by the differences attributed to water depth. Thus plants should be evaluated under optimal growth conditions which, unfortunately, have not been determined. The optimal conditions were not achieved in these tests since, in most cases, the plants did not achieve the potential as measured in the field (Table 12).

TABLE 12

Comparison of Fruit Dry Weight Obtained from Field and Tank Trials

site	fruit dry weight		florets per panicle	
	tanks	field	tanks	field
Pretties Bay	33.5	31.0/32.5	18.9	13/13.3
Irish Creek	20.5	25.7/24.9	25.7	47/36
Stafford Island	21.8	29.0/26.5	25.4	20
Easton Marsh	24.9	30/30.7	31.4	29.2
Calabogie Lake	23.8	37/34.5	20.6	24.3
Bellows Bay	27.7	no data	28.9	63

Note: multiple statistics are different years

Chapter III

DESCRIPTION OF LITTORAL HABITAT CHARACTERISTICS

3.1 INTRODUCTION

Lee (1979, 1981, 1982, 1983, 1984) has described in detail a wide variety of habitat parameters specifically associated with Zizania palustris in natural water bodies. These have been restricted to several specific experimental water bodies in northwestern Ontario and Minnesota. Thus while such work helps to explain the relationships of habitat variables and the growth of Z. palustris within specific water bodies, it describes neither the ranges to be encountered by the species in a region nor the commercial productivity of Zizania within these ranges.

The lack of comparability of data collected by various researchers using different methods has been a major problem in comparing the results of wildrice research. It has only been recently, with the work of Lee (1982, 1983, 1984) that a large body of data has been collected using consistent sampling and analysis techniques.

This chapter documents the ranges and time and spacial variations of some habitat variables and the relationships amongst them as found in the littoral zones of water bodies

within the study area. The ability of these variables to characterize water bodies and sites within the water bodies, when sampled in a one-time regional survey, is tested. The relationships between these habitat variables and fruit production by Z. palustris are considered in Chapter IV.

3.2 METHODS

3.2.1 Sampling Sites

During the 1981 field season sixteen water bodies, and usually several stations in each, were sampled (Appendix A).

During 1982 two transects were established across two areas of a major wildrice stand at Grassy Bay, Calabogie Lake (see Appendix A). This stand grows primarily on land flooded for hydro-electric power generation during the 1930's. One transect (AA) crossed the main channel with 12 stations at ten metre intervals. The vegetation was dominated by Z. palustris and Nuphar spp. except for the channel in which Ceratophyllum demersum L. and Elodea canadensis Michx. dominated with various species of Potamogeton and some Vallisneria americana Michx. present. The other transect (BB) extended from the shallowest area to the most open, deepest area with 11 stations at 50 metre intervals. The vegetation was mostly Z. palustris with Najas flexilis (Willd.) Restk. & Schmidt, Potamogeton spp. and occasional Myriophyllum spp.

Also during 1982 at McCullochs Mud Lake six pairs of stations were established (see Appendix A) to represent the diversity of habitats within the lake. Other water bodies were sampled at least once, several sampling stations being selected in each water body (Appendix A).

3.2.2 Sampling Regime

Various sites in the study area were sampled once only between June 16 and September 4, 1981.

The stations at McCullochs Mud Lake were sampled weekly from May 16 to September 4, 1982 for water and sediment variables. Water was sampled weekly and sediment biweekly at Calabogie Lake between May 20, and September 2, 1982 . Other sites were sampled once during August and the first week of September, 1982 with the exception of Haley's Lake which was sampled several times (Appendix B).

3.2.3 Sample Variables

The sampled variables are listed in Table 13. The variables in the first group are those which were readily measurable in the field, thus permitting weekly sampling at permanent stations during 1982. The second group of variables includes water borne nutrients which were easily sampled but require considerable resources and time to analyse. This group also includes sediment loss-on-ignition and bulk den-

TABLE 13

Sample Variables

Group I	water conductivity
	water redox potential
	water pH
	water dissolved oxygen
	water temperature
	sediment pH
	sediment redox potential
	sediment conductivity
Group II	water calcium
	water magnesium
	water potassium
	water zinc
	(water phosphate)
	(water iron)
	(water copper)
	(water manganese)
	sediment loss on ignition
	sediment bulk density
Group III	sediment pH (laboratory)
	sediment conductivity (laboratory)
	sediment extractable ammonium
	sediment extractable phosphate
	sediment extractable potassium
	sediment extractable calcium
	sediment extractable magnesium
	sediment extractable iron
	sediment extractable zinc
	sediment extractable manganese
	(sediment extractable copper)

Note: - parameters in parentheses were too low in concentration to be reliably measured by the methods used

sity which were easily sampled once only and considered to be relatively stable throughout the season. The third group are indicator and nutrient properties of sediments which required considerably more resources to collect and analyse than did the variables in the other two groups.

3.2.4 Field Sampling

Field measurements of water temperature, conductivity, pH, redox potential and dissolved oxygen concentration were taken at 10cm or 20cm intervals in the water column during 1981 and midway in the water column during 1982. A YSI model 57 dissolved oxygen meter (Yellow Springs Instrument Co., Yellow Springs Ohio, USA) was used to record temperature and dissolved oxygen concentration. Conductivity was measured with a YSI model 333 salinity-conductivity-temperature meter. Readings were standardized to 25°C using a regression developed from the measurement of one sample at various temperatures. The pH and redox potential were measured with a Fisher Accumet model 150 portable pH meter fitted with a combination pH electrode and a platinum combination electrode. The meter was modified to facilitate the use of both electrodes by the addition of a second pair of sockets and a switch between terminals. Commercial pH buffers of pH 7.00 and pH 4.00 were used to calibrate the meter.

Profiles in the water column were accomplished by suspending a weighted vinyl tube with a fixture to limit the water uptake to a horizontal plane at the set depth. Water was drawn by means of a 12V pump into open containers in which the pH, redox and dissolved oxygen probes were placed.

Water samples were collected from approximately 20cm depth, filtered through a glass fibre filter with vacuum and

placed into a new 500ml polyethylene bottle previously rinsed twice with some of the filtered water. Samples were stored in a cooler until they could be refrigerated at 5°C.

At each station cores of sediment were obtained using a piston type corer. This corer consisted of an acrylic tube (19mm inside diameter) with markings at 1cm intervals, the bottom edge tapered, and an inner plastic rod fitted with a rubber diaphram at the lower end. This corer eliminates the compression of sediment cores which can be extreme with other types of corers. Known volumes and intervals of the sediment were obtained with little observable mixing of the sediment profile. Cores of 50cm or 60cm were taken at each station and used for determination of bulk density and loss-on-ignition in the sediment profile. Ten centimetre sections of the sediment were extruded from the corer into preweighed, numbered glass vials with snap caps.

Sediment samples for chemical analyses were obtained by pooling the 2cm to 22cm interval of three to five cores located within 2m of the centre of the station. These were placed into 175ml polyethylene bottles leaving some air space for expansion, or into self-sealing polyethylene bags. Samples were kept in a cooler until they could be frozen. All samples separated into a liquid and solid phase during storage despite the extreme homogeneity of the samples when removed from the sediment. The liquid phase tended to leak from the plastic bags, thus many of the early samples were discarded.

On August 12 (day 224) measurement of the conductivity of the upper 20cm of the sediment profile was initiated. A Radiometer CDC104 conductivity probe was modified by removal of the outer glass cover over the sensing elements to permit direct contact with the sediment. A YSI model 33 conductivity meter was modified by the addition of a PL59 socket to accept the probe with a 33ohm resistor in series, and a switch between the two sockets. The modified probe was calibrated using a regression of readings of a series of conductivity standards measured with both the modified probe and the YSI probe. Conductivity measurements were standardized to 25°C using a regression of conductivities of one sample at various temperatures.

Measurements of sediment pH and redox potential were made at the stations in McCullochs Mud Lake and at other locations. Samples of the top 20cm or at specific intervals in the sediment profile were collected and the electrodes placed directly into the samples (these samples were not used for chemical analysis). Typically five samples were measured at each station. Initial equilibration time for the redox probe was long (typically 10 minutes or more). The redox probe had to be moved directly from one sample to the next as quickly as possible to avoid rapid oxidation of the electrode when exposed to air. Even with such care several minutes were required for the probe to equilibrate in each sample.

3.2.5 Laboratory Analyses

Water samples were analysed for ammonium, phosphate, potassium, calcium, magnesium, iron ,zinc, copper and manganese. Only calcium, magnesium, potassium and zinc were present in concentration measurable by the methods used. Analyses for nitrogen and phosphate were done using chemico-colourimetry (Stainton et al., 1975). All analyses for metals were done by atomic absorption spectroscopy (Stainton et al. 1975) using samples acidified with 3ml of 3M hydrochloric acid per 100ml. Appropriate blanks and standards were analysed with each sample series. Details of methods may be found in Appendix C.

The sediment profile samples of known volume were dried at approximately 85°C and weighed. From the dry weight a bulk density expressed as mg/ml was calculated. These samples were placed into dried, weighed crucibles and dried at 95°C before being fired at 430°C for 24 hours (Davies, 1974). The sample and crucible were cooled under vacuum in the presence of a dessicant and reweighed. The loss-on-ignition was calculated and expressed as a per cent of the original dry weight.

The frozen sediment samples were thawed at room temperature, the temperature recorded and the pH and conductivity measured as described under Field Sampling. The samples were extracted for nutrient analysis using methods modified from

Lee (1982). The extracts were analysed for phosphate, ammonium, potassium, calcium, magnesium, iron, zinc, copper and manganese.

The extraction process used was on a volume basis and involved the shaking of 20ml of the wet sediment sample in 50ml of extractant, gravity filtering, and collection of the filtrate for the analysis of the selected nutrients. The nature of most of the sediment samples permitted the stirring of the sample using a teflon-covered magnetic stir bar on a stir plate to keep the sample homogeneous while two subsamples of 10ml each were withdrawn using a plastic syringe with the outlet widened to 0.64cm. The total volume of the subsamples was estimated at 19.90ml (±0.07ml) by weighing similar samples of distilled water. In the case of samples too dense to subsample in this way, the samples were first stirred by hand, and cores of the sample taken using a 10ml plastic syringe with the end removed.

The subsamples were placed directly into approximately 50ml (48.67ml) of appropriate extractant in a 125ml Erlenmeyer flask. Extractants used were Bray extractant (0.05M ammonium fluoride; 0.1M hydrochloric acid) for phosphate, 2M potassium chloride for ammonium; 1M ammonium acetate for calcium, magnesium and potassium; and 0.1M hydrochloric acid for iron, zinc, copper and manganese (McKeague, 1978; Lee, 1982).

The extractant and subsample were shaken on a rotary shaker for one hour at approximately 45 rotations per minute to keep the material suspended. The extracts were filtered through Whatman number 1 paper filter prewetted with approximately 1ml of deionized water and the filtrate collected in polyethylene or polypropylene bottles. The extracts were stored at 5°C until analysed.

Samples were processed in the same sequence for all steps of the extraction and filtering procedure to reduce variation caused by extracting time. The rates of filtration, however, were not controllable and the variation in extraction time occurred, caused by differences related to sediment types and their rates of filtration.

The amount of water in each sample was estimated by placing two 10ml subsamples of the sediment sample into preweighed glass bottles and drying them at 85°C. The loss of weight was taken as the amount of water in the sample. This factor (estimate of the proportion of water in each sample) was used to adjust the volume of the subsample used in the extraction. The volume of the solution containing the ions is the sum of the liquid phase of the sediment subsample and the volume of the extractant used. (eg. 19.9ml x F + 48.67ml where F is the proportion of water in the 19.90ml subsample used).

Analysis for ammonium was accomplished using an indolphenol blue spectrophotometric method modified from Stainton et al. (1975). Since samples had to be diluted, a dilute reagent was used containing phenol and nitroprusside. (See appendix D for detailed notes on analysis methods). This reduced (a) the occurrence of a considerable error caused by incomplete mixing of reagents when added individually to the diluted sample; (b) the number of replicates required to achieve confidence in the analysis; and (c) the time required. Two or three replicates of each sample, together with blanks and known standards were run in each batch. Replicates with low absorbance (a result of incomplete mixing of reagents and sample) were dropped from the results of the analysis and samples were rerun if reasonable agreement between replicates was not achieved. The analysis was found to be accurate and stable if care was taken in agitating the subsample and reagents.

Phosphorous analysis was accomplished using the molybdate blue method (Stainton et al., 1975). No correction for arsenic was made. Reduced reagent was mixed daily. Samples were run in duplicate with blanks and standards in every batch. The analysis was very accurate and stable.

Analyses for calcium, magnesium, potassium, iron, zinc, manganese and copper were accomplished using atomic absorption spectroscopy. (Stainton et al. 1975). Dilutions were made using deionized water which was tested by the same

method, and using lanthanum buffer diluted 1:4 for calcium and magnesium to reduce interference (Stainton et al., 1975). Blanks and standards were run with each batch. No replicates were run.

All measurements were adjusted for dilution and are expressed as molar concentrations of the sediment samples as received in the lab after freezing.

3.3 RESULTS AND DISCUSSION - WATER PARAMETERS

Examples of the pertinent results are given in this section. Appendix B includes a full tabulation of the data.

3.3.1 Water Conductivity

Two groups of sites were distinguished by the conductivity of their water (Table 14). The majority of sites were in a group with conductivities from 118μS to 350μS (mean=167μS; s.d.=94μS). A second group of sites had conductivities between 750μS and 950μS, these being rivers or creeks draining farmland. Z. palustris was found in both groups in varying abundance. The range of conductivities is similar to that described by Crowder et al. (1977) in southeastern Ontario.

The majority of sites had a constant conductivity throughout the water column (Figure 11 A). However, at some sites (eg. James Island) conductivity increased with depth (Figure 11 B). An increase close to the sediment was often

TABLE 14

Water Conductivity of Sites

Site	Mean Water Conductivity (µS) 1981	1982
Calabogie L. AA	-	240
BB	-	118-256
Bellows Bay		306
Bennett L.	200	165
McCulloch Mud L.	270	260
Haleys L.	218	240
Muskrat Mud L.	-	208
Rosedale Ck.	-	142
Stafford Is.	143	143
Purdons Mud L.	160	-
Easton Marsh	230,950,750	-
Irish Creek	345	-
Pretties Bay	181	-
Big Rideau L.	199	-
Constant L.	240	-
Wiltse Ck.	305	-
Ferguson Mud L.	270	-
James Is.	247	-
Stevens Ck.	790	-
Jock R.	800	-
Barbers Ck.	900	-

Note: - multiple values for Easton Marsh are various locations

observed, presumably caused by diffusion of ions from the sediment. Some sites showed irregular increases or decreases in conductivity associated with submerged vegetation.

The possible range of water conductivity within a site is well expressed by Figure 12 which shows the values along transect BB at Calabogie Lake for two dates and the seasonal mean. The stations with the highest conductivity were closest to shore, tended to be the shallowest and tended to have the greatest abundance of decomposing vegetation. While transect AA of the same lake did not have much variation along its length (the interval between stations was only 20m), it was consistently higher at all but the shallowest station in transect BB.

Figure 11: Water Conductivity Profiles

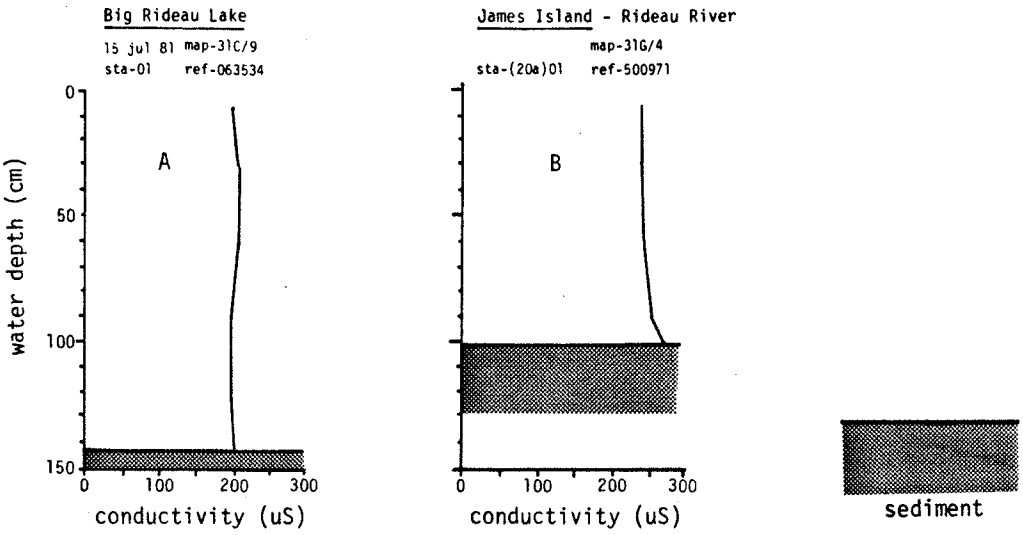
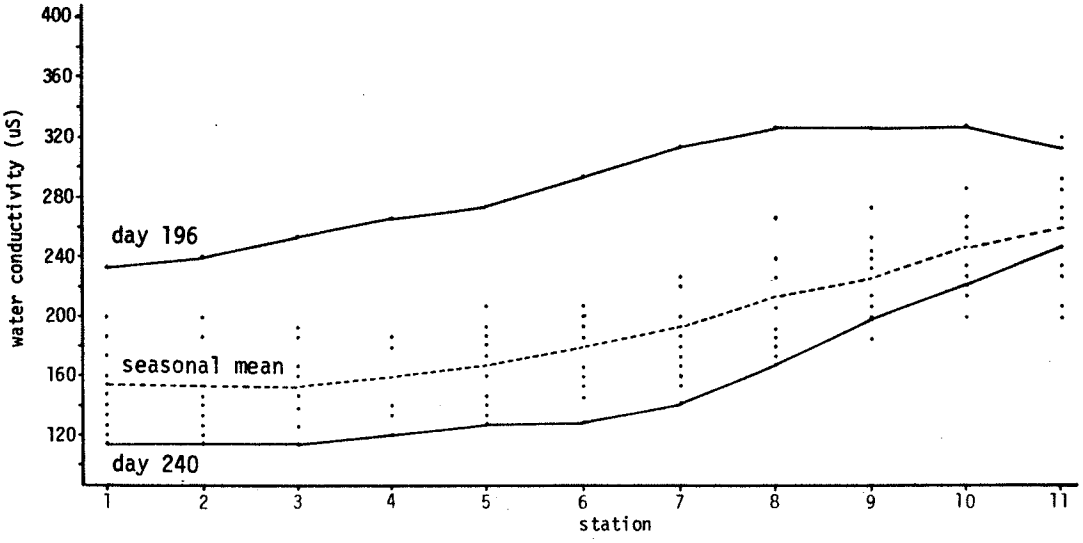
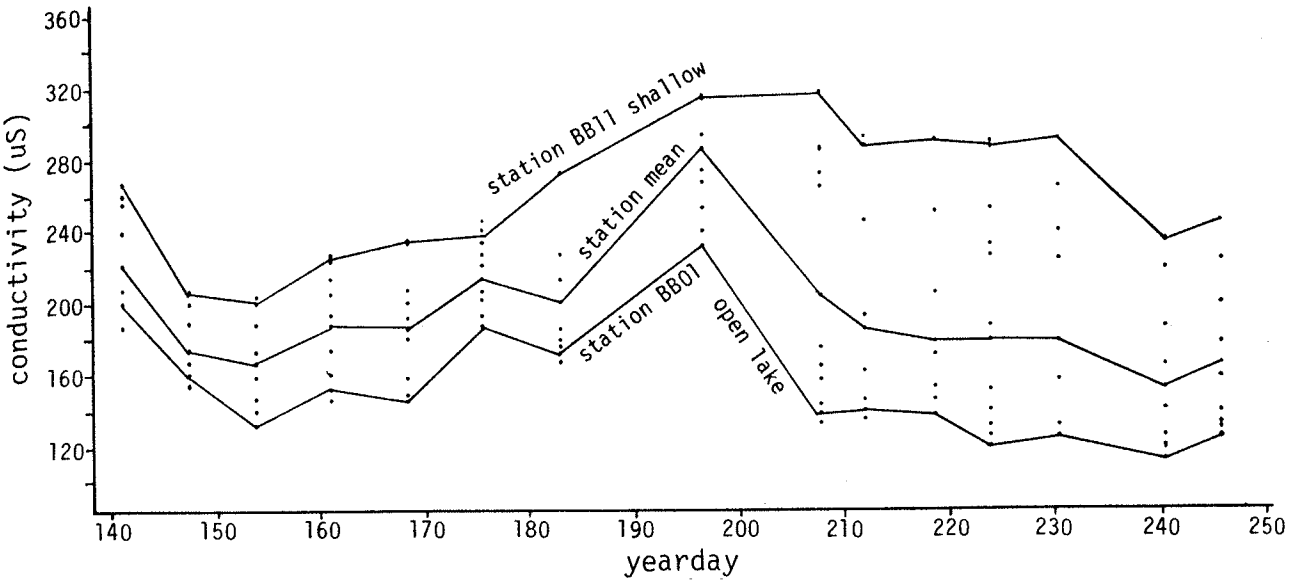


Figure 12: Water Conductivity - Transect BB - Calabogie Lake



Fluctuations of water conductivity throughout the season were recorded. Differences between sampling dates were found at all sites at McCullochs Mud Lake and Calabogie Lake, but the patterns of increase and decrease in water conductivity were not similar. A distinct pattern of seasonal shift in water conductivity was found at transect BB at Calabogie Lake (Figure 13). A change in the variation along the transect is apparent also, with an increase in between station variance as the Z. palustris plants become emergent and presumably influence the water exchange between the open lake (station B1) and the shore (station B11). An increase in the decomposition of detritus may also have occurred during this period. Such an increase in variation between stations was not evident at transect AA in the same lake.

Figure 13: Seasonal Water Conductivity - Calabogie Lake 1982

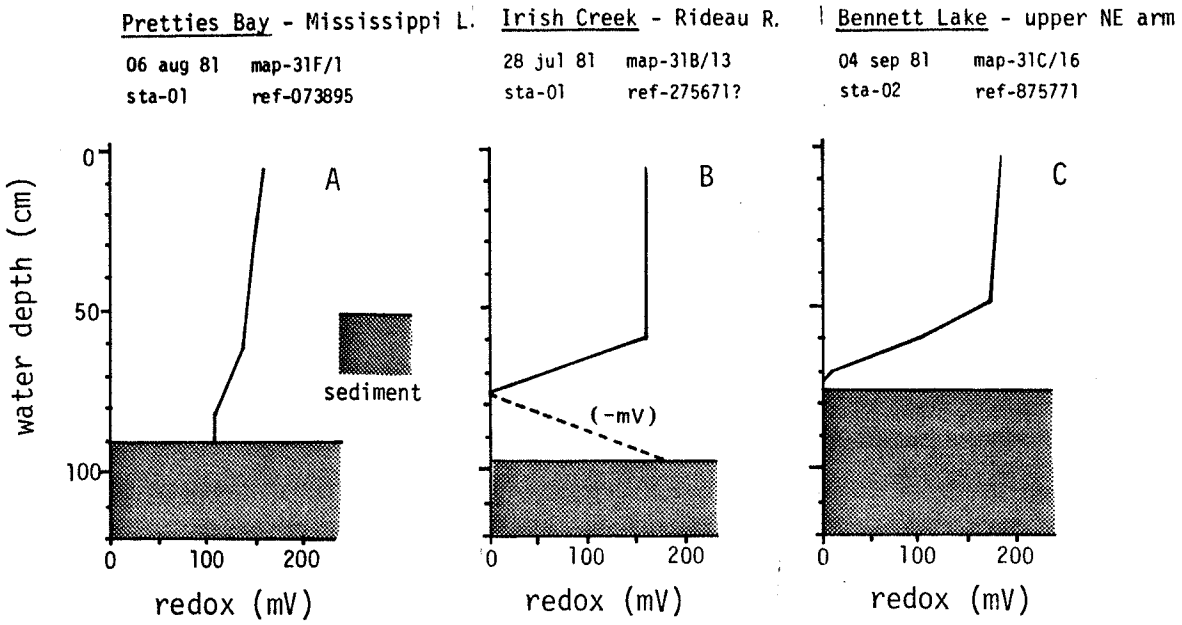


Note: -some observations are hidden
data points indicate range only

3.3.2 Water Redox Potential

Some characteristic and significant profiles of redox potential were identified in the water column. In most cases the redox potential was found to be well within the positive range down to the sediment interface (Figure 14 A). Some cases were found where a negative redox potential existed in the water above the sediment (Figure 14 B), and in many cases, a less positive potential occurred near the interface (Figure 14 C) suggesting that more reduced molecules were diffusing from the sediment. These zones of less positive or negative redox potentials were associated with low dissolved oxygen in the water (see Figure 17 G, page 73).

Figure 14: Water Redox Profiles



Distinct variations in water redox potentials were found between water bodies and through the season. The measurements ranged from less than +60mV to +250mV.

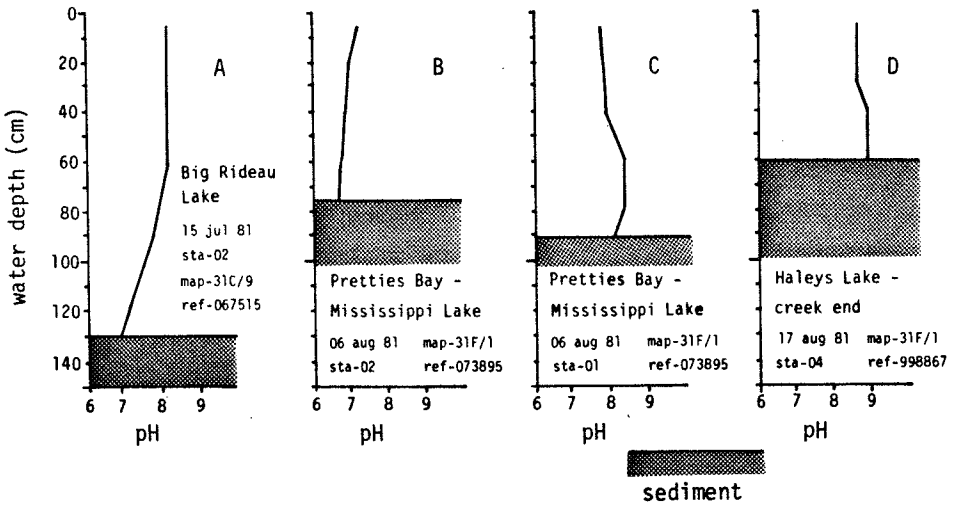
3.3.3 Water pH

The water pH of the various sites sampled was well distributed between pH 7.0 and pH 8.5 (mean=7.71; s.d.=0.52). No groupings or trends were apparent. These pH records were slightly lower than those recorded by Crowder et al. (1977) in southeastern Ontario (mean pH 7.9).

The variation in water pH throughout the water column was not consistent. While most stations tended to show a decrease in pH with increasing water depth at various gradients (Figures 15 A & B), some stations would show an in-

crease in pH with depth (Figures 15 C & D). Both cases even occurred at different stations within the same water body (Figures 15 B & C).

Figure 15: Water pH Profiles



The reduction of pH with increasing water depth may be due to the diffusion of organic acid molecules from the sediments which were found to have very consistent pH around 6.7.

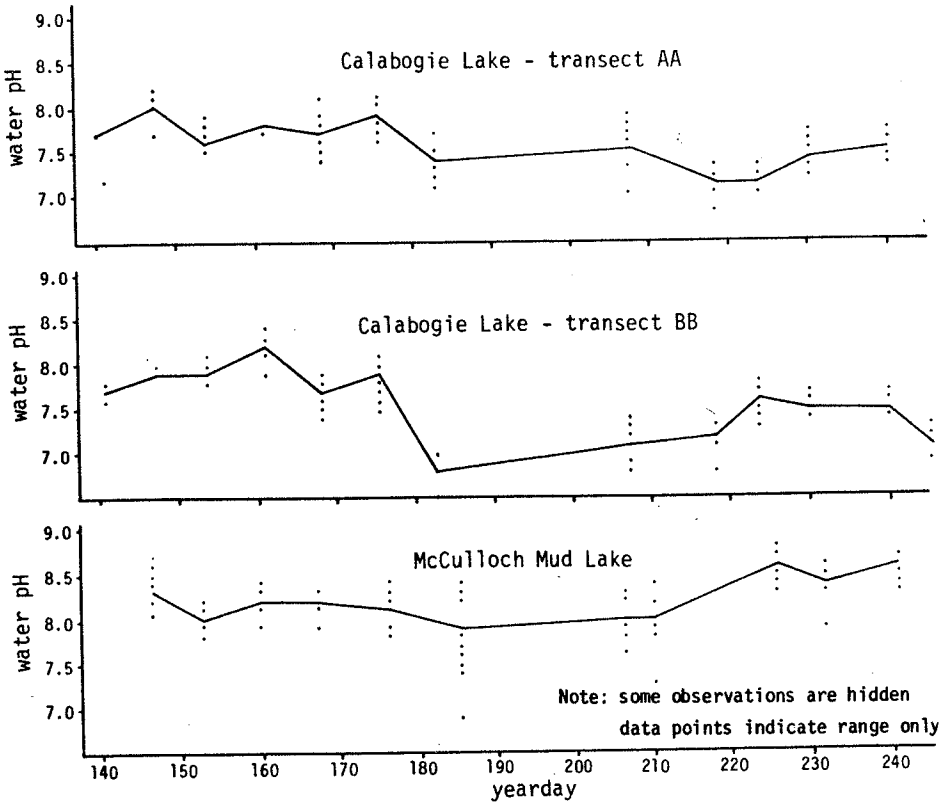
Very little variation of water pH between stations at sites in Calabogie and McCullochs Mud Lakes was found at any one time. However, on some days differences between the two transects at Calabogie Lake were evident.

Differences in pH between Calabogie and McCullochs Mud Lakes could be found for most of the sampling periods. Analysis of variance of these and other water bodies sampled af-

ter yearday 225 indicates significant differences between sites.

Sites and stations were found to vary in water pH throughout the season as illustrated for transect BB at Calabogie Lake by Figure 16. Transect AA at Calabogie Lake and the stations at McCullochs Mud Lake had less variation. The seasonal trend is not very distinct, but a slight decline in pH from the spring to the middle of the season and then a slight increase in the latter part of the season is apparent.

Figure 16: Seasonal Water pH Variation Within Sites - 1982



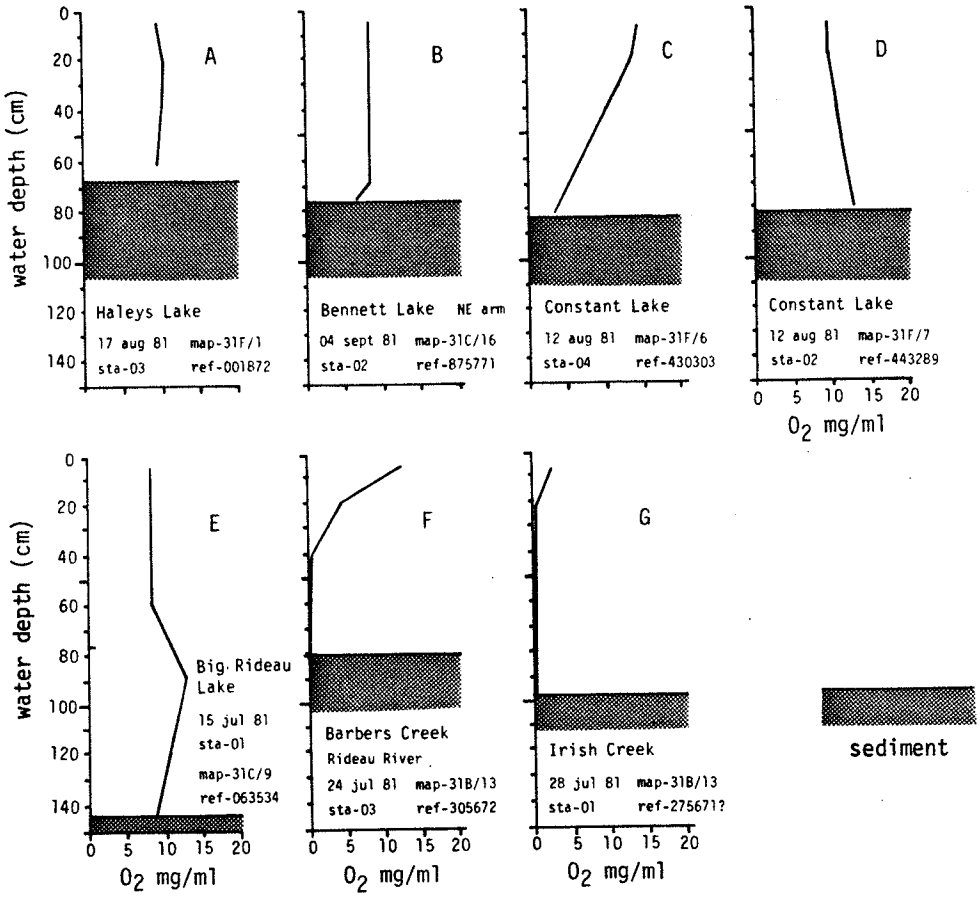
3.3.4 Dissolved Oxygen

The majority of stations had oxygen profiles similar to Figure 17 A with some having sharp gradients towards lower oxygen near the sediment interface (Figure 17 B). A gradual gradient from high to low oxygen with increasing water depth was found at only one site with submerged vegetation present (Figure 17 C) whereas another bay of the same lake had a profile of increasing oxygen with water depth (Figure 17 D). Where dense vegetation was encountered, two different situations were found (Figures 17 E & F). In the first case (a mesotrophic situation) an increase in oxygen was encountered below the layer of vegetation. In the other case (a very eutrophic situation) very low levels of oxygen were recorded. Also at one site where Z. palustris plants were rooted in a suspended mat of organic matter, profiles of very low dissolved oxygen concentrations were encountered. Both stations at this site had the same profile (Figure 17 G).

On any day differences in oxygen concentration between transects or within transects at Calabogie Lake were found, but these were not consistent from one week to the next.

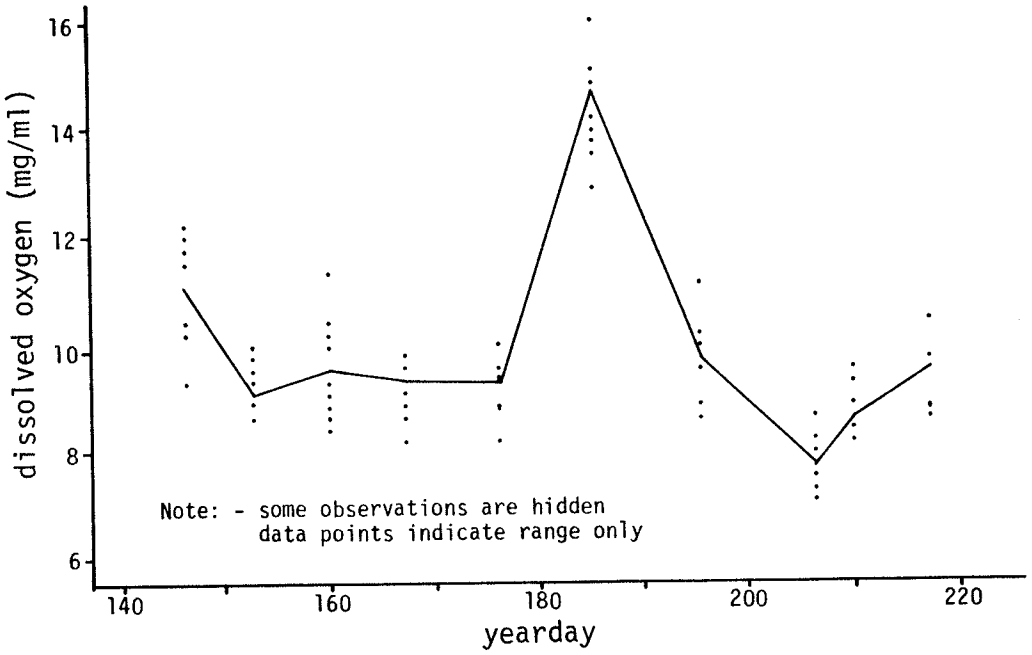
A greater variation of dissolved oxygen readings occurred between the stations in transect AA, possibly due to variation in the density of decomposing wildrice straw and other vegetation which characterized those stations.

Figure 17: Dissolved Oxygen Profiles



The dissolved oxygen concentration of the water at all sites was at least near saturation and frequently above. The variation through the season was greater than the variation between stations as illustrated by Figure 18.

Figure 18: Seasonal Water Dissolved Oxygen - McCullochs Mud Lake 1982

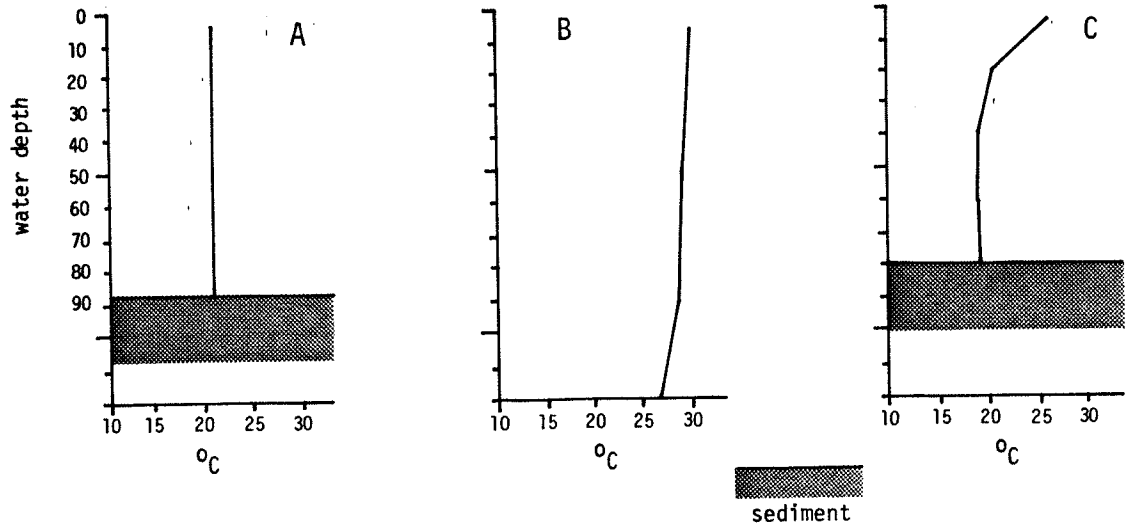


3.3.5 Water Temperature

The survey of water profiles conducted in 1981 showed that most of the littoral sites were similar to McCullochs Mud Lake in that they had no or little variation of water temperature throughout the water column (Figure 19 A). On a large lake, Big Rideau Lake, similar to Calabogie Lake, a temperature gradient was found (Figure 19 B, Figure 20). The sites which did show a stratification of temperature in the littoral zones were those at which vegetation was well developed (Figure 19 C).

The temperature profiles at the two recording stations were different as illustrated in Figures 20 and 21. At

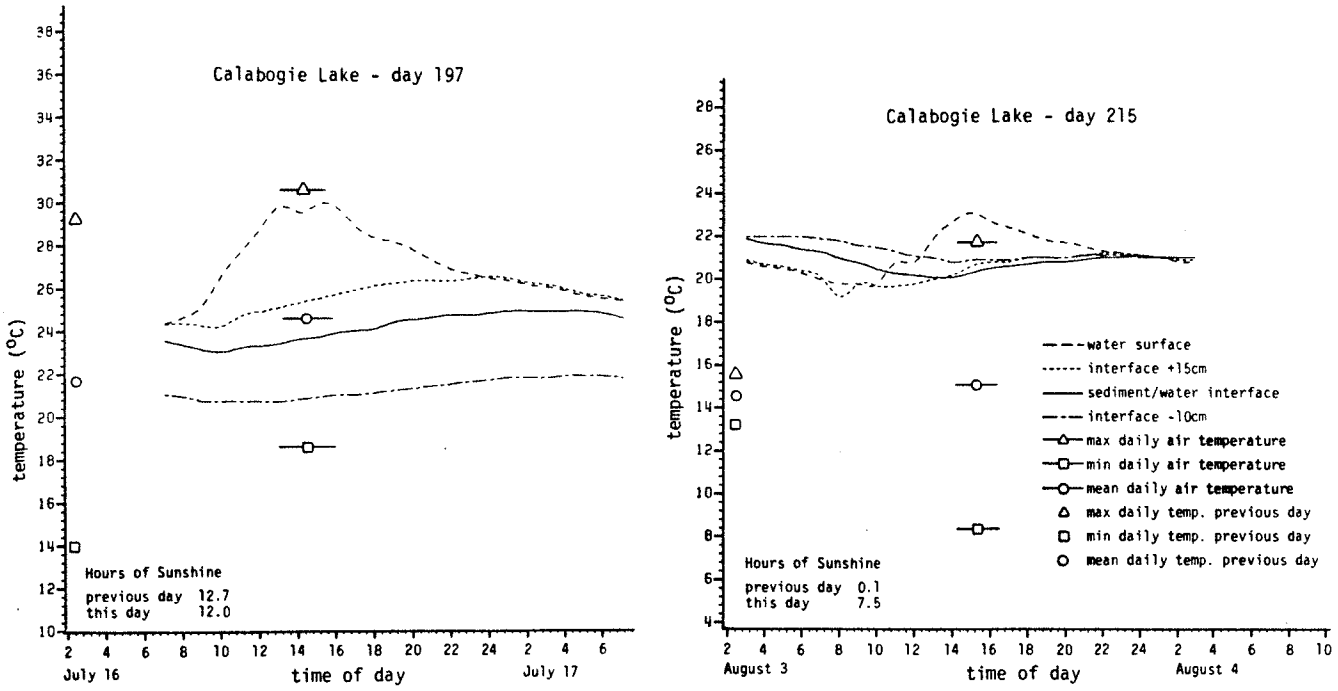
Figure 19: Water Temperature Profiles



McCullochs Mud Lake all levels of the water profile had similar temperatures. At Calabogie Lake the temperatures at the various levels segregated with the daily warming trend and later converged with a typical time lag between depths. This difference in regimes was attributed to the shallow water depth and lack of vegetation at McCullochs Mud Lake permitting greater radiation penetration and mixing of the water by convection and wave action.

Hourly temperature recordings at Calabogie and McCullochs Mud Lakes indicated a wide daily variation in water temperature (as much as 7°C) with the greatest variation occurring at the water's surface. The sediment temperature (10cm below the water-sediment interface) fluctuated daily, but at an entirely different magnitude (typically <1°C each day).

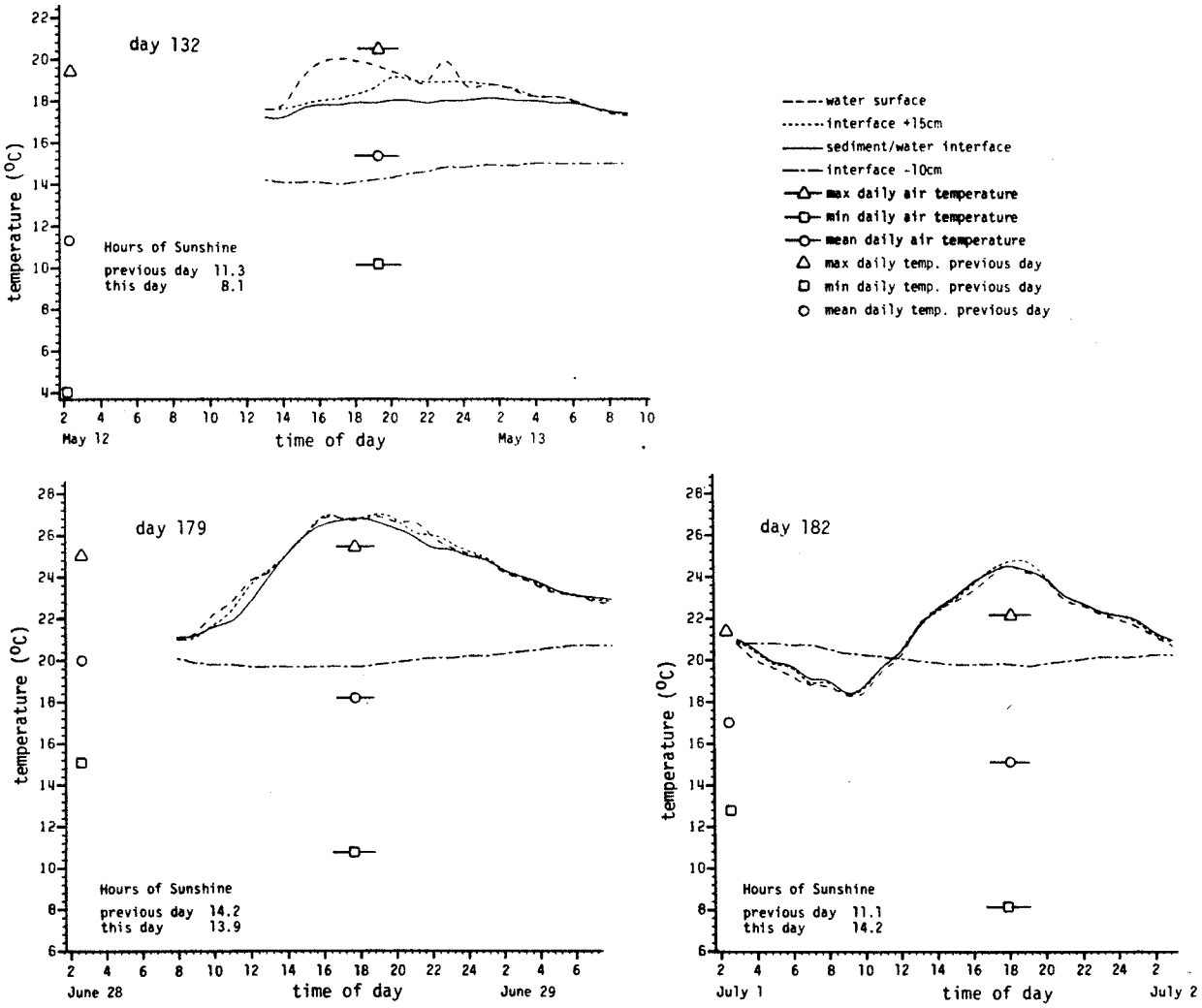
Figure 20: Hourly Water and Sediment Temperature - Calabogie Lake



The daily temperature period began its warming cycle later than 7:00am, reaching a temperature high around 4:00 to 7:00pm and declining through the night at the surface, but still rising at greater depths towards equilibrium around 3:00am (Figures 20 and 21).

Three characteristic daily cycles were selected to illustrate daily fluctuations. The first (Figure 21 A) is the first day recorded at McCullochs Mud Lake on May 12 and 13, 1983 as the entire water body slowly warmed early in the

Figure 21: Hourly Water and Sediment Temperature - McCullochs Mud Lake



season. It illustrates the slow warming of the sediment and the temperature differential between the sediment and the water.

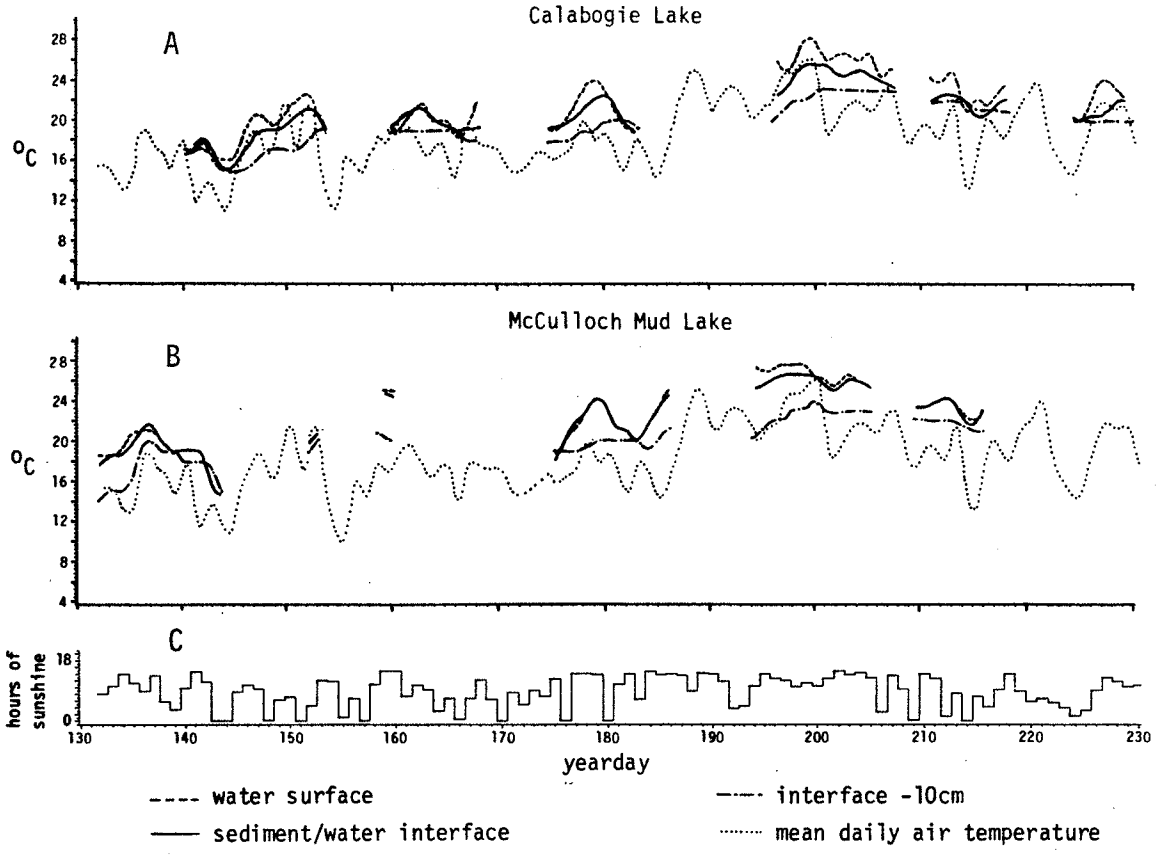
Typical warm and sunny days are illustrated by Figures 20 A and 21 B. At Calabogie Lake (Figure 20 A) a time lag through the profile is apparent with the sediment temperature continuing to decline until noon and then rising above the previous day's high through the night.

The third case illustrates a cooling trend, either in mid season (Figure 21 C) or later (Figure 20 A). The cool air temperatures of the preceeding day and early morning at first depressed the water temperature but later the radiation and increasing air temperatures of the day managed to bring the water temperature above that of the sediment.

Some factors influencing daily temperature fluctuations are suggested by these results. Firstly the water temperature frequently rose above the maximum daily air temperature (Figure 20 B and Figure 21 B and C) suggesting that most of the heat input is by way of solar radiation rather than conduction from the air. The fact that the sediment temperatures were almost always greater than the mean daily temperature during the growing season indicates the ability of the water body to act as a solar collector. Secondly the insolation and the air temperature of the previous day influenced the latent heat of the water and, to a lesser extent the sediment, thus affecting the relationship betwen water and sediment temperature and the water temperature shift which can be achieved on any day. Thirdly the latent heat of the water and particularly the sediment tend to stabilize the seasonal fluctuation of the water body. This is illustrated by the fact that sediment temperatures were usually greater than the mean daily temperature. A fourth component, that of biologically produced heat, is also suggested by the fact that sediment and water temperatures rose above daily maximum air temperatures.

The seasonal fluctuations in water temperature at the two recorder sites at Calabogie and McCullochs Mud Lakes are illustrated in Figures 22 A and B respectively. The mean daily air temperature recorded at Smiths Falls and the daily hours of sunshine at Ottawa (Environ. Can. Monthly Reports) are also illustrated (Figure 22 C).

Figure 22: Seasonal Water and Sediment Temperature - Calabogie and McCullochs Mud Lakes - 1982



The temperature in the sediment was consistently less than either the water or sediment interface and showed less short term fluctuation. The greatest fluctuations occurred

in the spring (yeardays 132 to 145) when a period of cold followed a warm period. At this time it can be expected that the deeper sediments were still cold thus acting as heat sinks to more readily lower the sediment and water temperatures when air temperature and solar radiation was reduced. The sediment temperature was more stable later in the season despite varying water temperatures, suggesting that the deeper sediments had less temperature differential and thus would act as a stabilizing influence on the water temperature rather than a cooling influence.

The aquatic temperature environment was more stable and often warmer than the air throughout the growing season. The sediment at 10cm below the interface was even more stable, both daily and seasonally, although slightly cooler than the water. Such stability is probably an advantage to rooted aquatic plants such as Z. palustris, aiding their acquisition of nutrients.

3.3.6 Water Borne Nutrients

The ranges of the measurable water borne nutrients in the region are given in Table 15. The values were well distributed within those ranges.

Differences in nutrient concentrations were apparent between stations in the same water body. The two shallow stations at Calabogie Lake (AA03 and BB11) were more similar to

TABLE 15

Ranges of Water Borne Nutrients at Sites

Nutrient	minimum (μM)	maximum (μM)
calcium	455	1291
magnesium	139	595
potassium	3.8	40.8
zinc	0.06	0.37

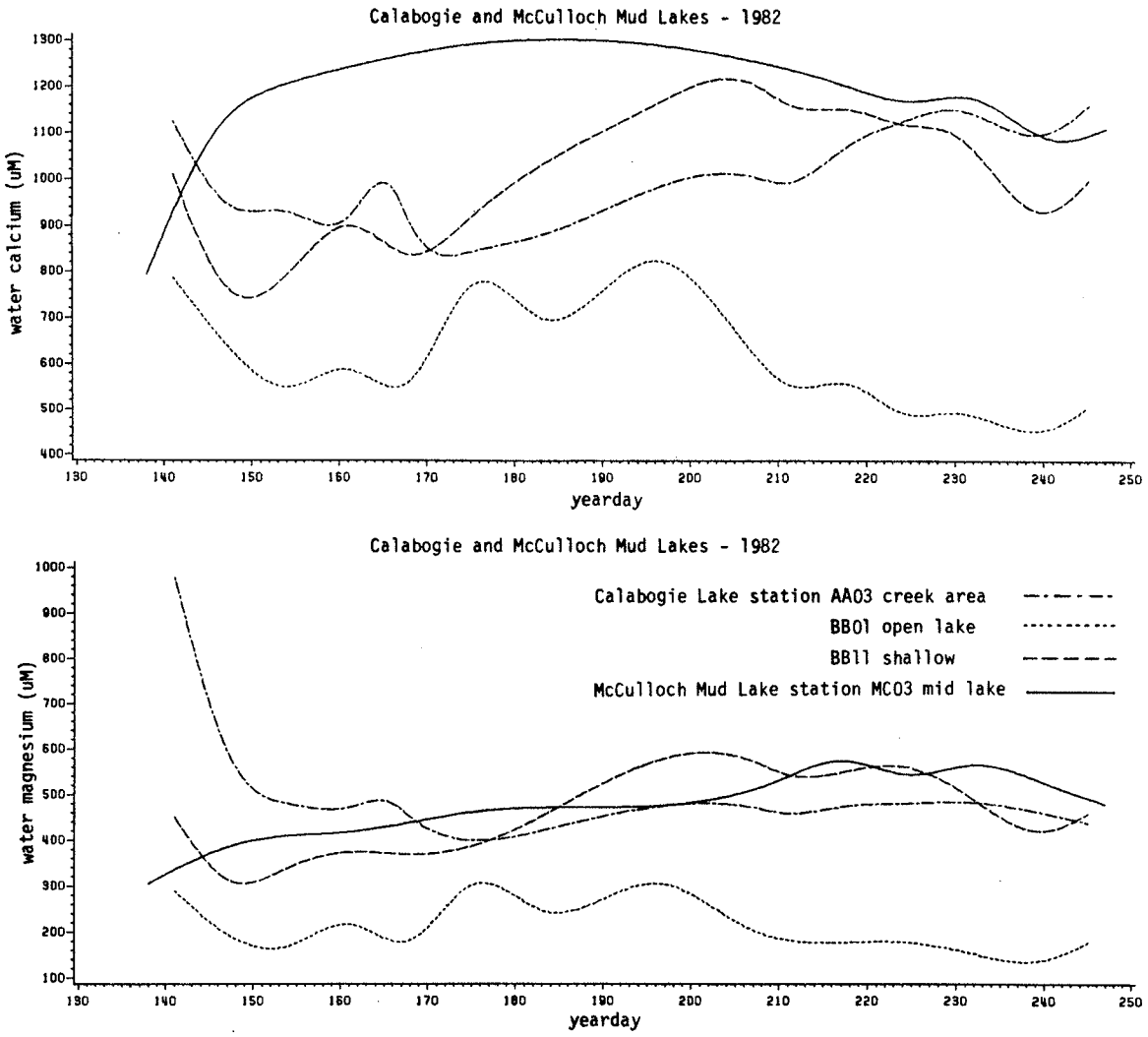
(concentrations are the means for any one site at any sampling time)

each other for calcium and magnesium than they were to the deeper station (BB01) which had consistently lower concentrations and followed a different seasonal pattern (Figure 23). This was attributed to the nearby shore acting as a source of nutrients for the shallow sites; the greater abundance of detritus from which nutrients may be released; and stronger diluting and mixing effects in the deeper, less vegetated site.

Water potassium concentrations (Figure 24) were often greater at the deeper site BB01 suggesting that the mechanisms controlling calcium and magnesium may not apply for potassium. The growing vegetation at the shallower sites may well be taking up potassium during the season.

The minor nutrient, zinc, did not differ between the two stations exposed to the lake (stations BB01 and BB11) but was substantially higher until late in the season at the shallower station AA03 located up the creek (Figure 25). This area supported more varied and more robust vegetation, suggesting that the creek may transport nutrients into the area.

Figure 23: Seasonal Water Calcium and Magnesium - 1982



It is apparent from Figures 23 and 24 that water bodies differ in their dynamic characteristics for water borne nutrients. In order to evaluate the significance of these differences amongst the sites in the survey region an analysis of variance was done using data from all sites only after yearday 165 so that Calabogie and McCullochs Mud lakes were not overly represented by samples taken during a period when

Figure 24: Seasonal Water Potassium

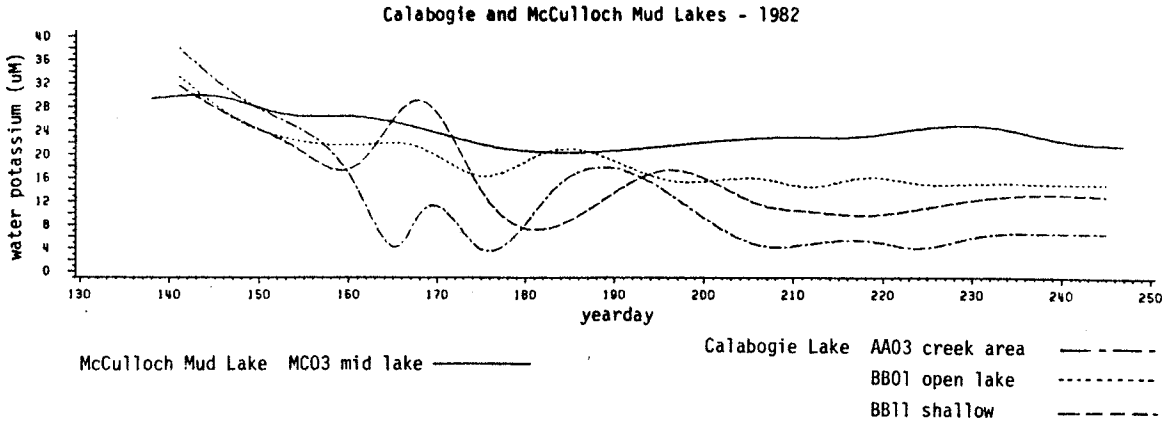
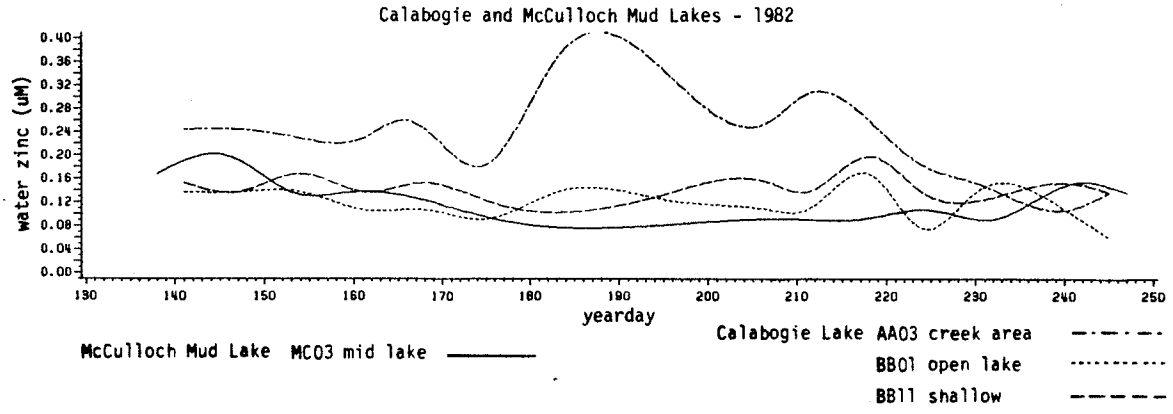


Figure 25: Seasonal Water Zinc



other lakes were not sampled. Each of these nutrients were significantly different between some sites. A Waller Duncan comparison of means (Table 16) identified two major groupings and several subgroupings of sites for calcium - one group with concentrations above 1018μM and another below 788μM. The shallow sites at Calabogie Lake were in the former group and the deep site was in the latter. The same two groups of sites were formed for magnesium and the Calabogie Lake sites were split in the same manner, the shallow sites

TABLE 16

Water Borne Nutrients Amongst Sites

Calcium			Magnesium			Potassium			Zinc		
site	n	(μM)	site	n	(μM)	site	n	(μM)	site	n	
MC	7	1181.6	BE	1	586.18	MU	1	45.78	AA	11	0.224
BE	1	1147.7	MC	7	524.65	BE	1	36.83	BBS	10	0.145
HA	5	1074.1	BBS	10	495.10	PU	3	35.28	PU	3	0.122
BBS	10	1056.0	HA	5	491.65	HA	5	34.83	BE	1	0.122
AA	11	1018.4	AA	11	455.85	BN	5	28.75	HA	5	0.119
PU	3	788.0	MU	1	343.48	MC	7	22.98	BBD	11	0.111
BN	5	748.5	RO	1	279.72	ST	2	21.87	MC	7	0.109
MU	1	723.6	BN	5	256.11	BBD	11	16.44	BN	5	0.107
RO	1	617.5	PU	3	231.73	BBS	10	14.12	MU	1	0.107
ST	2	614.4	BBD	11	204.78	AA	11	6.37	ST	2	0.107
BBD	11	593.7	ST	2	164.95	RO	1	5.12	RO	1	0.092

AA - Calabogie Lake - creek area
BBD- Calabogie Lake - open lake
BBS- Calabogie Lake - inshore
BE - Bellows Bay - Ottawa River
BN - Bennet Lake - NE arm
HA - Haleys Lake - centre lake
MC - McCulloch Mud Lake
MU - Muskrat Mud Lake
PU - Purdons Mud Lake
RO - Rosedale Creek - Rideau River
ST - Stafford Is. - Mississippi River

being in a group with magnesium concentrations greater than 455μM and the deep site in a group with less than 344μM.

Potassium was also significantly different between some sites with ranges overlapping except for two sites at the lower end of the range (means less than 7μM) and Muskrat Mud Lake at the upper end of the range (mean 46μM). Again Calabogie Lake sites were segregated.

Only the one site up the creek at Calabogie Lake had a significantly higher mean zinc concentration than all the other sites.

The seasonal trends of calcium and magnesium concentrations were found to differ greatly between Calabogie and McCullochs Mud Lakes (Figure 23). Whereas at Calabogie Lake the earliest samples had among the highest concentrations,

at McCullochs Mud Lake they had their lowest. The initial drop in concentration of both nutrients at Calabogie Lake was followed by a rise through the summer, but declined at stations BB01 and BB11 during the late summer. A sharp rise in calcium concentration was evident at McCullochs Mud Lake during the early season and a slight decline was found in the later season. Magnesium concentrations at McCullochs Mud Lake continued to rise gradually over the season with a slight decline late in the season similar to that of calcium.

Water potassium concentrations also declined during the early season at Calabogie Lake stations. They fluctuated throughout the season, becoming more constant after July, but never rising appreciably (Figure 24). A gradual, slight decline during the early season at McCullochs Mud Lake was also noted, but the concentration remained fairly stable throughout the rest of the season. The initially high levels at Calabogie Lake were consistent with early decomposition of vegetation, releasing highly soluble potassium (Davis and van der Valk, 1978; Klopatek, 1978).

Fluctuations in water zinc during the season were minor except for a peak at the most vegetated site at Calabogie Lake during mid summer (Figure 25).

The shallow nature of McCullochs Mud Lake was likely responsible for the rise and the relative stability of nut-

rient concentrations. Spring flooding from runoff flushed nutrients, and then the warming trend and reasonably stable conditions leading to sediment decomposition may have been responsible for these relatively constant concentrations.

At Calabogie Lake, the decomposition of vegetation, large volume runoff and wave action on the more open lake could have been responsible for the more varied nutrient concentrations observed. Station BB01, located in open water, was subject to the greatest fluctuations and acted independently of the more shallow stations.

3.4 RESULTS AND DISCUSSION - SEDIMENT PARAMETERS

3.4.1 Sediment pH and Redox Potential

One set of sediment pH and redox potentials was recorded for McCullochs Mud Lake on May 18 and 19, 1982. A mean pH of 6.75 was found on each of the two days (s.d.=.08 and .09; n=70). Other spot measurements throughout the region were similar with pH measurements in the range 6.5 to 6.8. The redox potential ranged from -250mV to -340mV (mean=-309mV, s.d.=25.19mV, n=69).

Forty-four samples were collected from McCullochs Mud Lake, frozen, stored and subsequently measured for pH in the laboratory. These were compared with the direct field measurements, although none of the samples were those measured in the field and they were taken over the entire season.

The mean pH of these samples was 6.59 (s.d.=0.16; n=44) which is significantly different from the measurements in the field at the 0.1% probability level. This drop in pH suggests some biological changes to the samples upon freezing and subsequent handling.

The differences of sediment pH between the stations at McCullochs Mud Lake were found to be marginally significant by an analysis of variance ($f=2.91$; $p>f=0.033$). No distinct groups were evident. Most stations ranged from pH 6.70 to pH 6.86, however the pair of stations at the mouth of the lake (MC06F & MC06S) were at one end of the range (6.70 and 6.63 respectively). Due to possible measurement error, it cannot be concluded that there were significant differences in redox potential between stations.

3.4.2 Sediment Conductivity

The conductivity of sediments measured in the field ranged from 25μs at Calabogie Lake to 608μs at the Rideau River.

The conductivities measured in the lab after frozen storage ranged from 320 to 928μS with an outlier at 1055μS. The samples were well distributed over the range with a slight skew to the lower values caused by a small group of samples over 840μS. Samples from the major sites were distributed throughout the range. Values obtained from samples collect-

ed from Lake of the Woods by Atkins (pers. comm.) and measured on saturated paste and interstitial water extracts ranged from approximately 150μS to approximately 450μS.

Sixty-one of the frozen samples were measured for conductivity in the field, frozen, thawed and again measured. These latter values were considerably higher than those obtained in the field from fresh samples. A regression analysis indicated a poor fit (r^2=.242) between the two measurements. Thus it cannot be assumed that the laboratory measurements represent or even correlate with the conductivity as found in the field. Despite this lack of correlation the laboratory measurements may still be useful in classifying sites.

Each of the six pairs of stations at McCullochs Mud Lake were sampled in the field at four dates between yeardays 225 and 232. A Waller-Duncan comparison of means indicated no significant difference between the means of all the stations for each date.

Similar tests at Calabogie Lake indicated some significant differences of sediment conductivity between sampling dates at transect BB.

These measurements were made on samples taken during the latter part of the season (within a 22 day period) and cannot be assumed to represent the fluctuations throughout the season. The lab conductivity did rise between yeardays

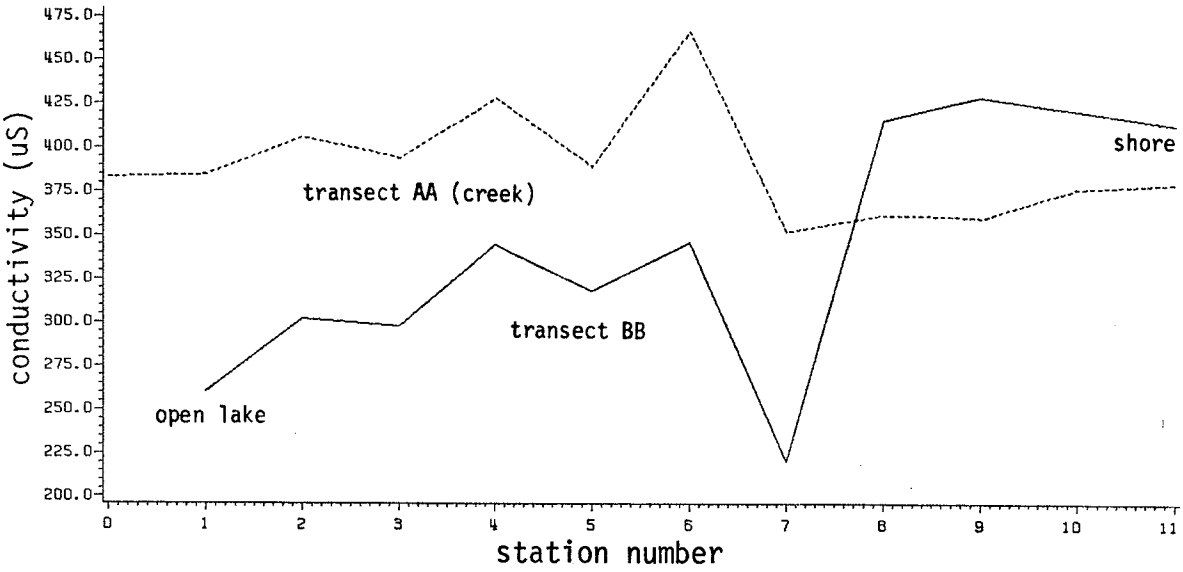
207-211 and yeardays 245-247 at McCullochs Mud Lake and Calabogie Lake stations.

The differences in sediment field conductivity between stations within a site were considerable at both McCullochs Mud Lake and Calabogie Lake as illustrated in Figure 26. At McCullochs Mud Lake the differences between stations were highly significant ($f=10.00$; $p>f=.0001$). Stations with higher sediment conductivity were those closest to shore. A definite trend towards higher sediment conductivity at the shallow end of the long transect BB, Calabogie Lake is apparent and, while the trend is not so obvious for transect AA, there were distinct differences between stations. The trend along transect BB is barely evident in the case of lab conductivities, providing another reason for lack of confidence in lab conductivities.

Station BB07 (Figure 26) had a very low conductivity (approx. 220μS). A very low bulk density was also recorded for this station, indicating some local anomaly.

At all sites the variances between stations were found to be significant. However, further analysis indicated that the variance between stations was not significantly greater than the variance between sampling dates at the 0.01 level of probability for each of the three sites (MC,AA,BB). Thus two stations within the same site measured on different weeks may or may not have significantly different sediment conductivities.

Figure 26: Sediment Field Conductivity at Calabogie Lake Stations



The reasons for increased conductivity with proximity to shore may be the same as hypothesized for water conductivity which had the same trends, these being less water for dilution; less water movement; more leaching of ions from growing and decomposing vegetation; and the proximity to the shore with its greater source of ions.

Highly significant differences in sediment field conductivities were found between the three major sites (MC, AA, BB) even though two were in the same bay of the same lake. The variance between sites was greater than the variance between sampling dates.

3.4.3 Sediment Loss-On-Ignition and Bulk Density

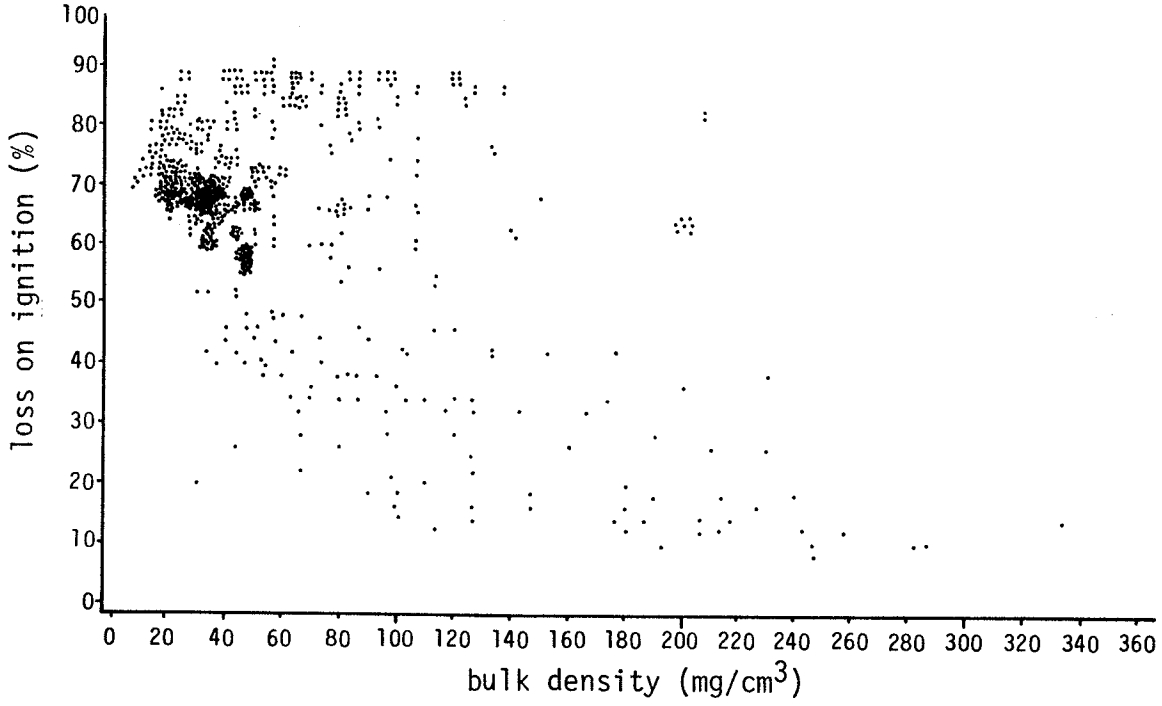
Most of the sites sampled had 60% to 90% loss-on-ignition, but a few ranged as low as 10%.

The distribution of bulk densities was skewed heavily to the low end of the range beginning at less than 20mg/cc and extending to 340mg/cc. A $\log_{10}$ transformation of the bulk densities was found to normalize the distribution.

An inverse relationship was identified between the sediment loss-on ignition and the sediment bulk density (Figure 27). This was expected since the ignitable organic component of the sediment was less dense than the nonignitable mineral component. A wide variance in this relationship is also evident suggesting that both variables may be useful in describing the sediments. Linear regression analyses of these variables, their inverses and logarithms gave low r values.

Several typical profiles of the physical variables of the sediment were found. Many lakes were deeply infilled (as much as 3m) with loose organic matter yielding profiles with very low bulk density and high loss-on-ignition varying little with depth (Figure 28 A). Other sites were typified by a slight rise in density and reduction of loss-on-ignition with depth (Figure 28 B) suggesting some ongoing processes of decomposition or mineralization throughout the profile. Consistent profiles were also found in a riverine, backwater situation (Figure 28 C), but in this case the densities were

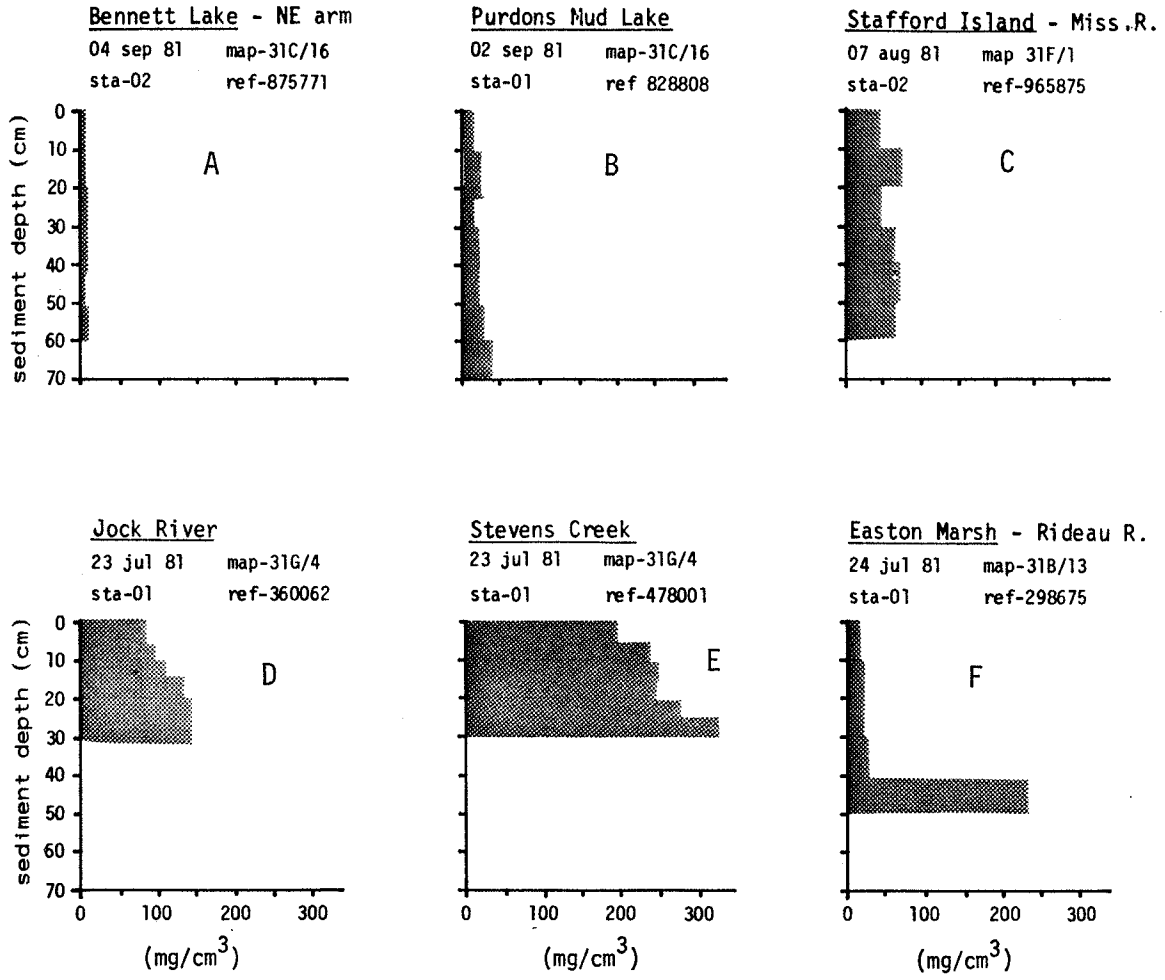
Figure 27: Relationship Between Sediment Loss-On-Ignition and Bulk Density



higher and the loss-on-ignition lower. These stations were probably subject to siltation. Sharp gradients towards high densities occurred in such situations where water flow was greater (Figure 28 D). In creeks on clay soil a more pronounced gradient and higher densities were observed while loss-on-ignition remained low and decreased with depth (Figure 28 E).

Two other types of profiles were associated with the presence of distinct strata. In one situation (Figure 28 F) a fast rise in density and drop in loss-on-ignition was due to underlying mineral (clay) soils within 50cm of the sediment interface. In the other case which occurred on a lake

Figure 28: Sediment Bulk Density Profiles



flooded some 50 years ago, high loss-on-ignition was recorded at greater depths. Examination of this profile revealed calcareous layers and the presence of Chara sp. Thus the high loss-on-ignition was attributed in part to the loss of carbonates during ignition and not solely to organic matter loss. A mud lake with a marl bottom was also found to have such a profile of loss-on-ignition.

The variation of loss-on-ignition and bulk density of the sediments was very small within the sites at McCullochs Mud Lake and Calabogie Lake. A slight gradient of loss-on-ignition along transect AA at Calabogie Lake was evident (Figure 29).

While no significant pattern of variation in bulk density were found at these sites, the variation within profiles at the Calabogie Lake stations was extreme (Figure 30) due to the coarse organic nature of the sediment resulting from the flooding of a wooded area some fifty years prior.

Significant differences in bulk density and loss-on-ignition were identified between sites using analysis of variance and Waller-Duncan K-ratio comparisons of means. Several groups were distinguishable for bulk density with some overlapping amongst groups (the Bellows Bay site (BE) was well above the other sites). The loss-on-ignition variable distinguished differences between sites more effectively (Table 17). Seven distinct groups were identified.

Loss-on-ignition was considered the more useful of the two measurements (except when carbonates were present) since it provided more discriminating results and was less subject to the sampling variations encountered for bulk density.

Figure 29: Sediment Loss-On-Ignition Along Transects - Calabogie Lake

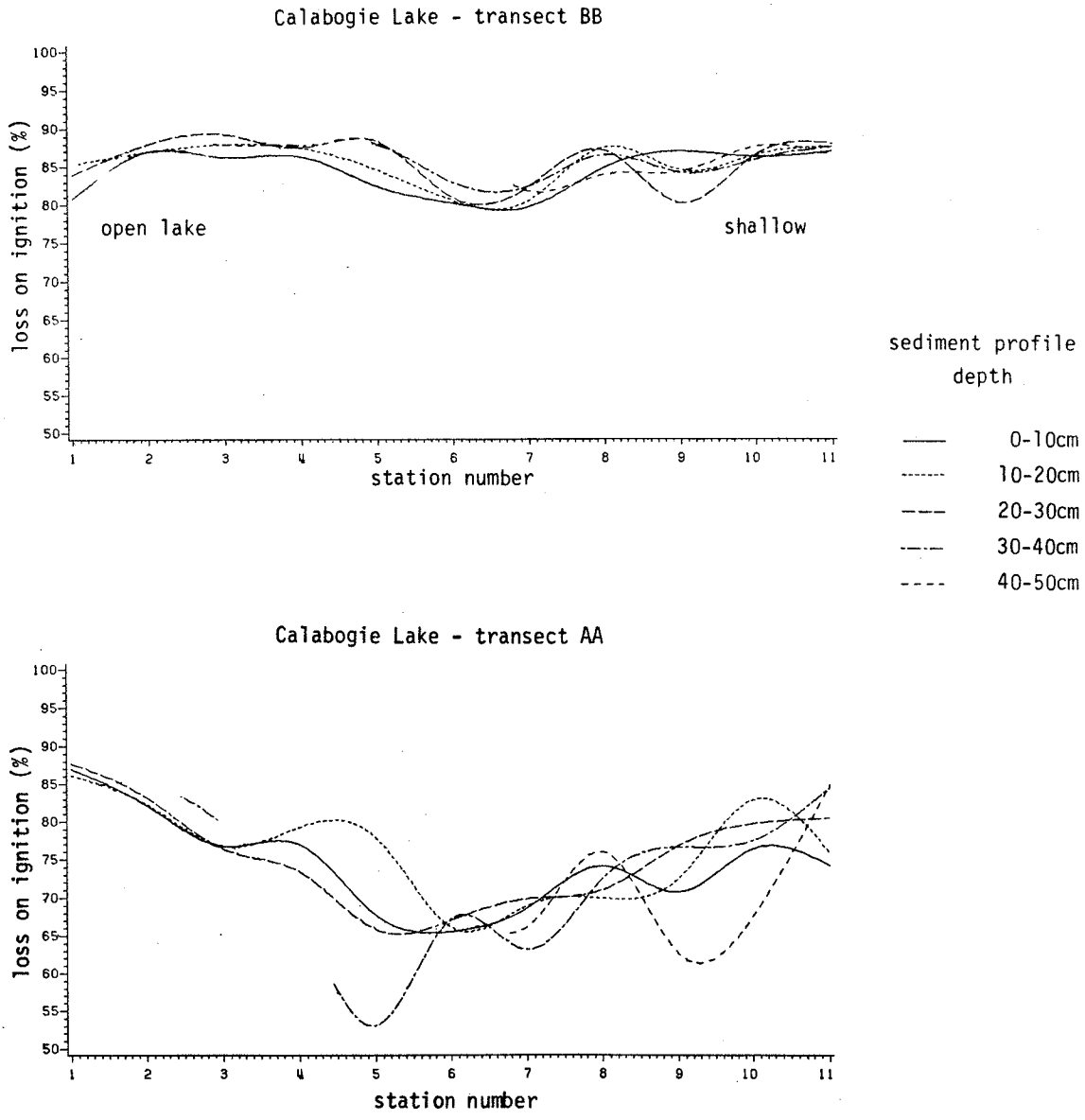


Figure 30: Sediment Bulk Density Along Transects - Calabogie Lake

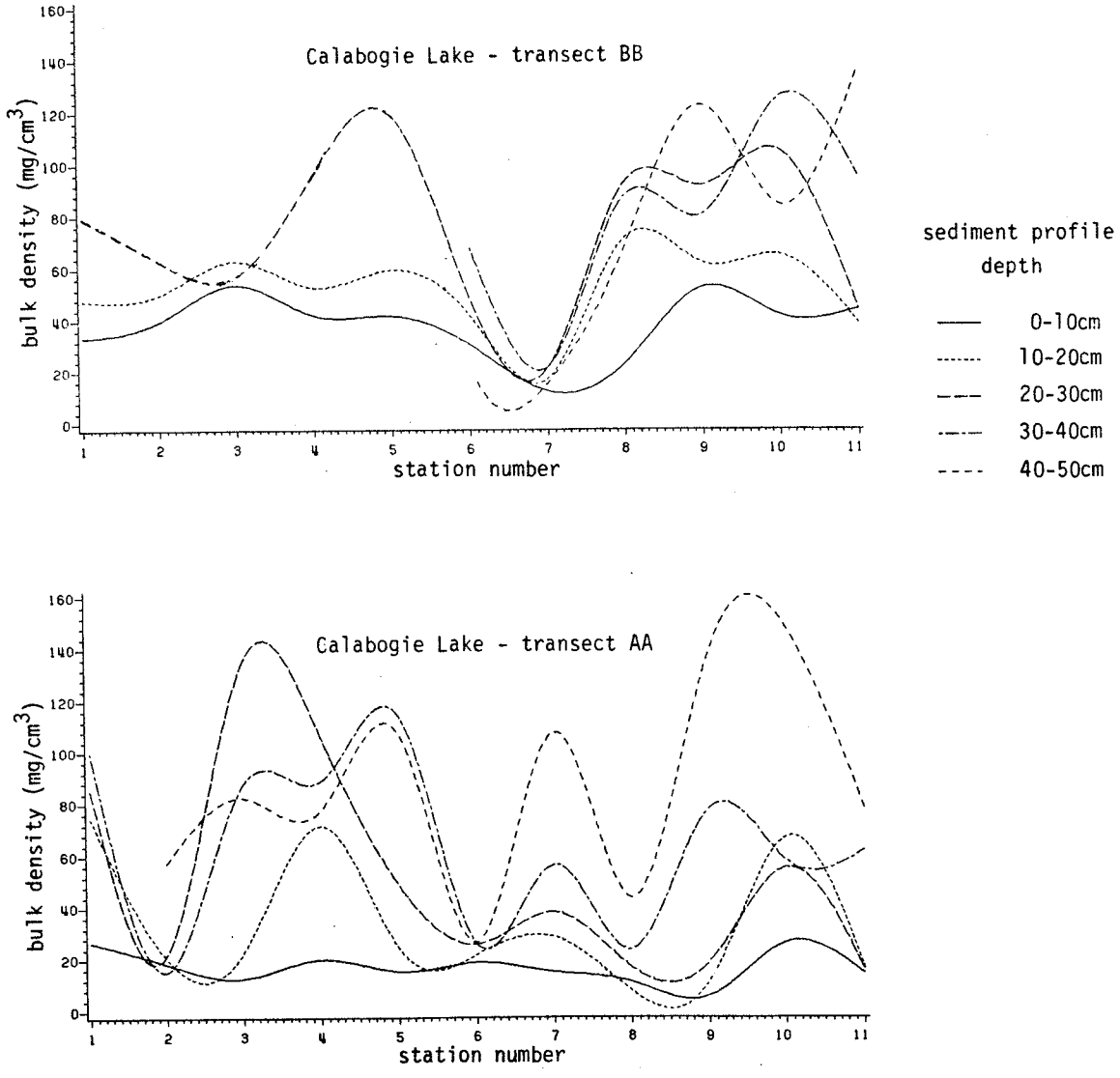


TABLE 17

Sediment Loss-On-Ignition Amongst Sites

Grouping	Mean LOI (%)	n	Site
A	85.54	11	Calabogie Lake - transect BB
B	75.95	11	Calabogie Lake - transect AA
B B			
B	73.53	5	Bennett Lake - NE arm
C	67.94	11	Haleys Lake
C C			
C	66.06	14	McCulloch Mud Lake
D	58.03	4	Rosedale Creek - Rideau River
E	43.76	4	Muskrat Mud Lake
F	36.09	6	Purdons Mud LAke
F F			
F	33.99	4	Stafford Island - Mississippi R.
G	15.42	5	Bellows Bay - Ottawa River

means with the same letter are not significantly different

Kratio=100 df=65 mse=18.82 F=170.81
critical value of T-1.768
minimum significant difference=4.42

3.4.4 Sediment Chemical Parameters

The means, standard deviations and ranges of sediment chemical variables are given in Table 18. No other comparable data were available for the region, but directly comparable results were available in the work of Lee (1982, 1983, 1984) and Atkins (1983) for the northwestern Ontario and Lake of the Woods regions. They indicate similar distributions.

While the distributions of these variables tended to be normal within a site, the majority of the sites sampled were at the lower end of the overall range. The sites with higher values had much wider ranges. Insufficient samples were collected to indicate the normality of their distributions.

TABLE 18

Sediment Chemical Characteristics

Variable	mean	n	s.d.	range
sed lab pH	6.48	137	0.188	6.05 - 6.95
sed lab conductivity	556.73µS	137	133.188µS	320 - 928µS
sed extractable ammonium	1.261mM	137	0.623	0.27 - 3.44mM
sed etractable phosphate	0.334mM	137	0.245	0.18 - 1.09mM
sed extractable potassium	0.197mM	137	0.135mM	0.059 - 0.749mM
sed extractable calcium	16.814mM	137	8.111mM	2.46 - 40.06mM
sed extractable magnesium	3.280mM	137	1.375mM	1.24 - 10.15mM
sed extractable iron	1.437mM	137	3.122mM	0.13 - 18.98mM
sed extractable zinc	0.060mM	137	0.038mM	0.005 - 0.200mM
sed extractable manganese	0.190mM	137	0.362mM	0.014 - 2.228mM

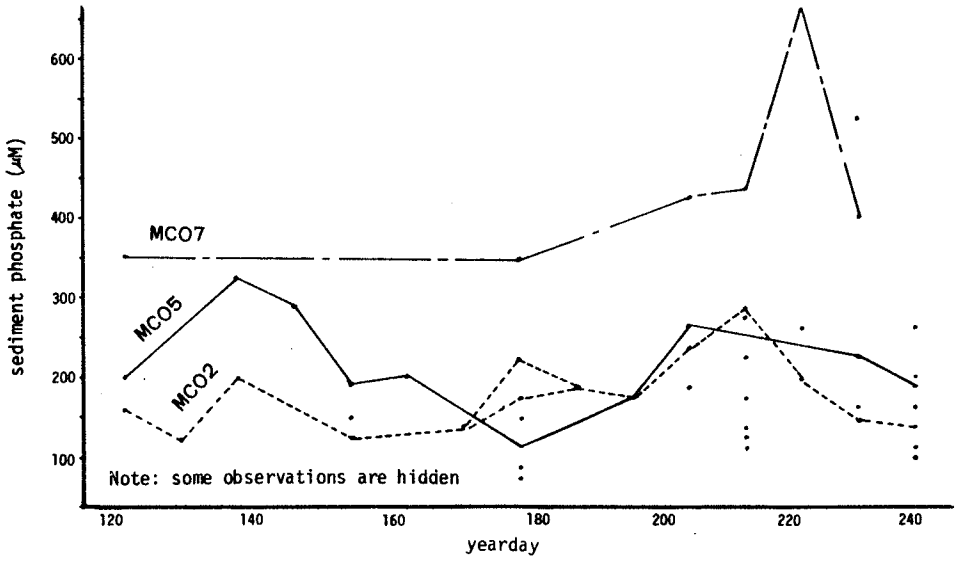
Variation in some nutrient variables between stations within a site was high, in particular for phosphorous, calcium and magnesium at McCullochs Mud Lake and the Calabogie Lake transects. Potassium and manganese had substantially different values between stations at McCullochs Mud Lake. The stations with higher concentrations at McCulloch Mud Lake were those adjacent to mineral shoreline.

The within-site coefficient of variation for each variable was high, particularly for iron and manganese. This is the result of most stations having extremely low values while a few had high values.

The variance between sites was significantly greater ($p<.001$) than the variance within the sites for all sediment nutrient variables using data from all time periods. This suggests that sediment nutrient analysis is effective in discriminating different sites.

In no case was the variation by time found to be, by graphic analysis, greater than the variation within sites (Figure 31). Since only one sample was taken at each station at each time, significant seasonal variation within stations could not be tested. Atkins (pers. comm.) and Lee (1979, 1983) indicate seasonal changes in sediment nutrient variables at stations. These do not appear to have a common trend despite the fact that trends within a station can be identified.

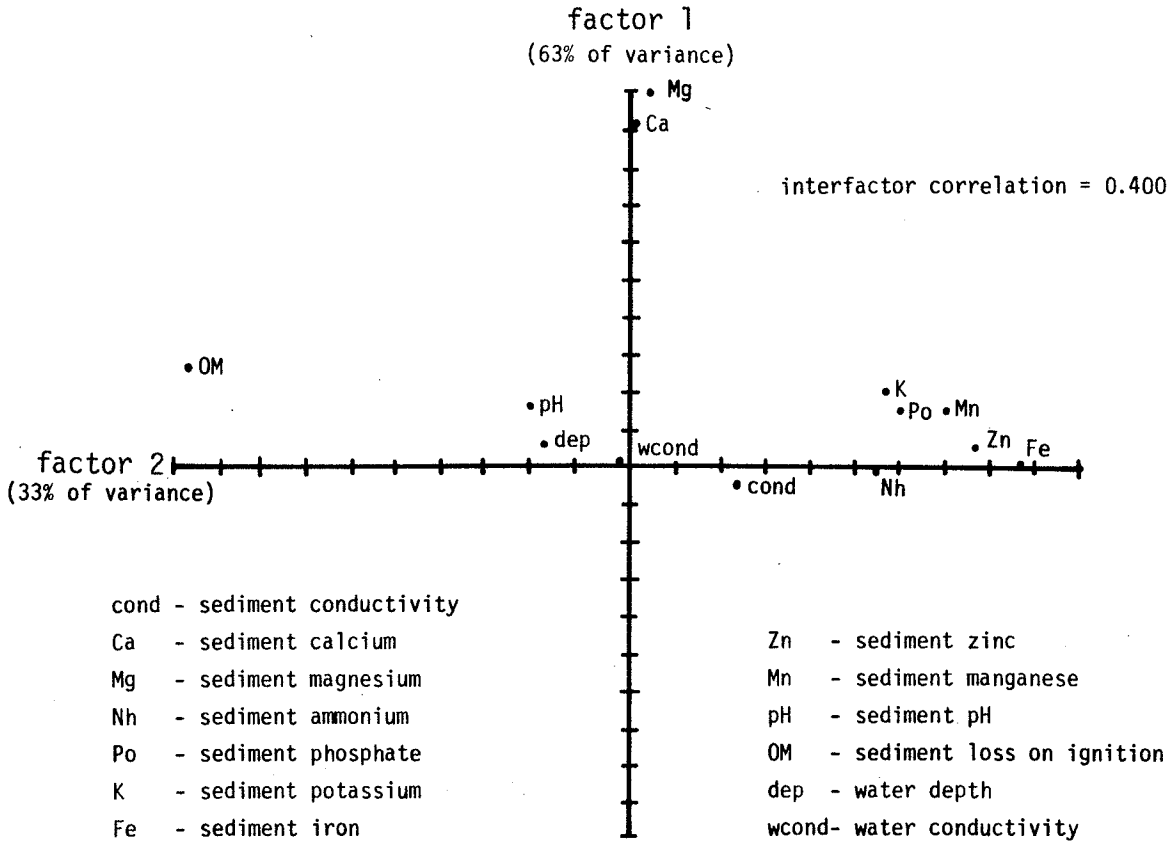
Figure 31: Seasonal Variation of Sediment Phosphate at McCullochs Mud Lake - 1982



3.4.5 Correlations Amongst Sediment Variables

A factor analysis of selected variables indicated the major factor to be weighted strongly by calcium and magnesium. (Figure 32). A second significant factor was weighted by loss-on-ignition and the other nutrients, in particular iron, zinc and manganese, which were correlated with phosphate and potassium and less closely with ammonium. Both factors were relatively independent of each other and pH, conductivity and water depth.

Figure 32: Factor Analysis of Sediment Variables



The negative relationship between loss-on-ignition and the major and minor nutrients indicated a higher presence of these nutrients in sediments with greater mineral content.

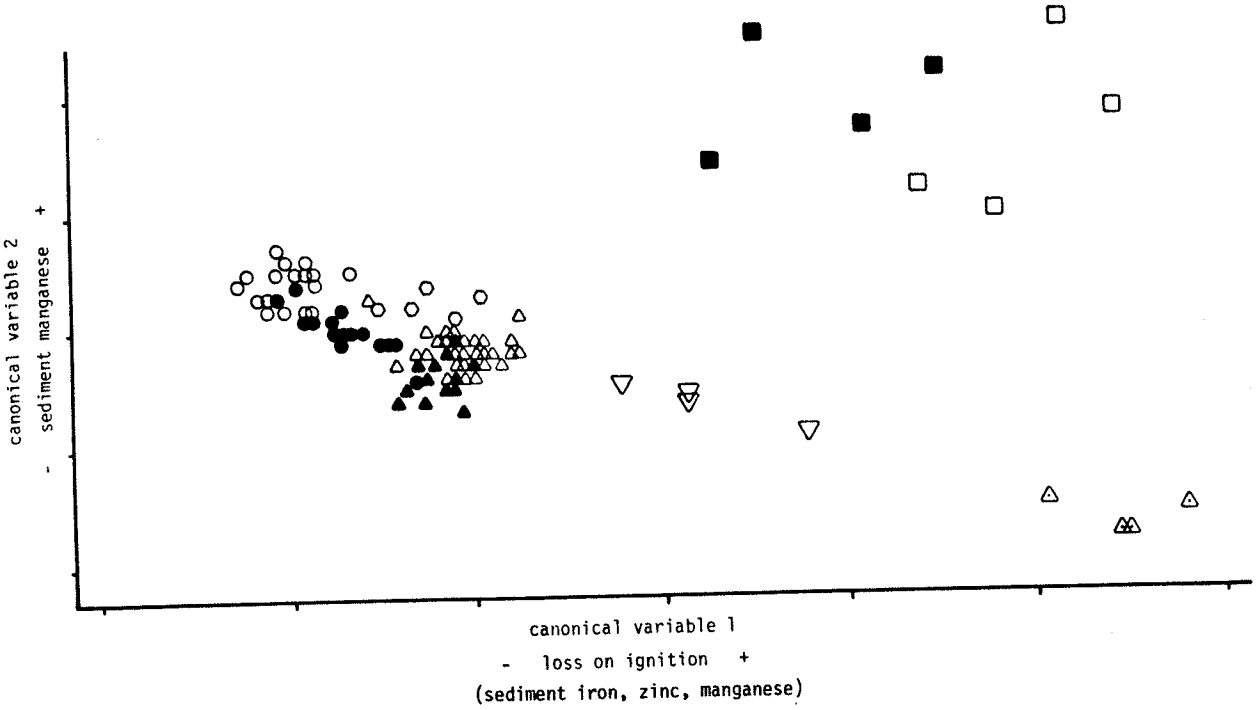
The groupings of the nutrient variables were similar to those found by Lee (1982, 1983, 1984) in northwestern Ontario with the exception that Lee indicates phosphorous more closely linked with loss-on-ignition than the minor nutrients.

3.4.6 Discriminant Analysis of Sites

The effectiveness of the selected variables to discriminate sites in a broad one-time survey was tested using a canonical discriminant analysis procedure (SAS - proc CANDISC). The data used were those for eight sites which were well sampled (including each transect at Calabogie Lake). Only the samples collected after yearday 165 were used in order to reduce time dependent variation.

The discriminant analysis (Figure 33) illustrated that there was sufficient variability between the sites sampled to easily discriminate and compare them based primarily upon sediment characteristics. The weighting effectiveness of each axis is given by the ratio of between site to within site variances and their F statistic, and the relative loading of each variable on the axis is given by the standardized canonical coefficients.

Figure 33: Canonical Discriminant Analysis of Littoral Sites



- ○ Calabogie Lake transect AA
- ● Calabogie Lake transect BB
- ○ Bennett Lake
- △ McCulloch Mud Lake
- ▲ Haleys Lake
- ▽ Muskrat Mud Lake
- □ Stafford Island - Mississippi River
- ■ Rosedale Creek - Rideau River
- △ Bellows Bay - Ottawa River

	STANDARDIZED CANONICAL COEFFICIENTS				
	CAN1	CAN2	CAN3	CAN4	CAN5
Varaiance Ratio	28.9	10.5	5.2	2.1	1.7
F score	35.8	24.2	17.6	12.8	10.4
Ammonium	0.2801	0.2651	-0.3273	0.6200	-0.5056
Phosphate	-0.6187	-0.6647	-0.4594	-0.1951	0.1411
Potassium	0.2839	-0.2717	0.9042	1.2100	0.1803
Calcium	-0.0089	0.2967	-0.6455	0.7062	-1.4537
Magnesium	-0.3433	-0.6853	-0.0653	-0.2210	2.2240
Iron	1.0412	-1.3447	-2.4634	0.1560	0.7819
Zinc	1.2053	0.7170	0.7113	-1.2584	1.2960
Manganese	1.2128	3.8705	1.0663	0.4217	-0.8527
L.O.I.	-2.6814	1.8597	-0.4116	0.4749	1.5282
FieldCond.	0.1415	-0.6004	1.1790	0.3500	-0.0598

The principal axis was influenced primarily by sediment loss-on-ignition which was the most stable and analytically reliable variable. The second axis was loaded mostly on sediment manganese. The third axis (not illustrated) satisfactorily separates the two transects from Calabogie Lake (AA and BB) and was influenced mostly by sediment iron.

The analysis correctly grouped stations by sites and placed similar sites together. The overlap of Haley's Lake (▲) and McCullochs Mud Lake (△) was expected since these two lake were very similar in physical characteristics and history, having been dry in the past and supporting very little vegetation.

3.5 GENERAL DISCUSSION

A major objective of this survey and analysis of spatial and temporal variation of environmental variables was to indicate which are sufficiently stable and discriminating to be useful in comparing sites without extensive seasonal sampling. It was concluded that water variables were not so useful as sediment variables due to their greater seasonal and within-site variations. The indicator variables (pH and conductivity) were not sufficiently discriminating to be useful. The sediment nutrient concentrations and loss-on-ignition provided good discrimination of sites despite their spatial and temporal variations. Thus it was concluded that the collection and analysis of sediment samples was most efficient for the purpose despite the greater resources required to analyse them. It was the secondary environmental factor (OM & nutrients) rather than the primary factor (Ca & Mg) which was most influential in the discrimination of sites.

The fact that sediment loss-on-ignition and minor nutrients satisfactorily discriminated between sites does not infer that these variables are responsible for observed variations in plant performance. This relationship is tested in Chapter IV.

The methods used to collect sediment nutrient variables were convenient in permitting storage of samples, and subsampling. The data were also comparable with those collected by Lee (1982, 1983, 1984) and Atkins (1983). The methods do, however, require some assumptions to be made. One such is the stability of the samples since oxidation to an unknown degree likely took place during handling and storage. The separation of liquid and solid phases and the distinct non-relative shift in conductivity and pH suggest that the forms or relative concentrations of nutrients may be very different from those found in fresh samples. The results and models obtained are valid, but only in terms of the specific procedure used. The extent and nature of the changes in samples after collection and upon freezing require detailed research if we wish to understand fully the availability of nutrients to aquatic macrophytes.

It is suggested that future work involving the extraction method should use vacuum filtration to aid in reducing the variance caused by the time of extraction and that the total volume of liquid in the system be assumed to be the volume of the filtrate which could be made up to a constant volume

(eg. 100ml) using deionized water. In this manner the total amount of ions extracted could be assumed to be contained in the final volume, neglecting the small proportion remaining in the solid phase and filter paper which could be rinsed with deionized water. Samples should be handled in random order so variations between analyses are randomly dispersed amongst the samples.

A second assumption is that the values obtained using the extractants are reasonable indications of the actual availability of the nutrients to the plants. Since some correlation with plant growth was obtained (see Chapter IV) this assumption must be correct to some extent, but the lack of correlation with some nutrients (eg. ammonium) may mean that the procedure does not correctly represent the availability of all. Other techniques, such as pore water sampling (Hesslien, 1976), may permit a higher level of confidence in the true representation of plant nutrient availability by reducing the handling required.

The methods used do not permit very good description of sediment nutrient stratification. The assumption that the bulk samples collected represent nutrient availability may not be valid if profile investigations reveal significant stratification. Methods of sediment nutrient analysis which lend themselves to profile sampling (such as interstitial water samplers - see Hesslein, 1976) should help clarify this.

Chapter IV

WILDRICE SUCCESS AND PERFORMANCE

4.1 INTRODUCTION

The specific habitat requirements of Zizania palustris L. (wildrice) have not been documented. Some generalities have been described (Dore, 1969; Rogosin, 1954; Moyle, 1944, 1945). Lee (1979, 1981--1984) has quantified some habitat variables associated with Z. palustris stands at several locations in Minnesota and northwestern Ontario. Those wishing to establish and promote wildrice in natural water bodies can only rely upon past experiences of trial and error or careful comparative observations of existing stands. The quantification of wildrice habitat characteristics and the relation of these to wildrice production, specifically seed production, would be of great benefit to those wishing to select sites for wildrice introduction and to predict the success. Such relationships would be particularly useful to those considering ameliorations to the habitat.

The objectives of the research described in this chapter were to relate the environmental characteristics of selected littoral areas in eastern Ontario to the success and failure of growth and seed production of wildrice.

During the autumn of 1981 and spring of 1982 four water bodies in eastern Ontario were seeded with Zizania palustris seed from one stand. The success (or failure) of the plants and a number of water and sediment parameters were measured at each seed plot and at other sites within the region, some supporting wildrice, others not. The data collected were analysed to determine the habitat parameters which discriminated between the successful and unsuccessful plots, and a model developed which correlates the performance of wildrice with the habitat parameters measured.

4.2 METHODS

4.2.1 Sites

In 1981 four water bodies were chosen for trial seeding of wildrice (McCullochs Mud Lake, Haley Lake, Bennett Lake and Purdons Mud Lake - see Appendix B). These were chosen because they represented large areas free of competing vegetation at suitable water depths for the production of wildrice. Three to six stations in each water body (Appendix A) were selected to represent the range of habitats available.

Two transects were established across an established stands at Grassy Bay, Calabogie Lake where there was known to be a variation in wildrice fruit production. The most robust of these plants appeared similar to those at Bellows Bay (the source stand for the seeding trials). Stations at other stands were sampled, including Bellows Bay and Musk-

rat Mud Lake. In addition, sampling for environmental variables was conducted at stations which did not bear wildrice at Muskrat Mud Lake and the Rosedale Creek area of the Rideau River (Appendix A).

4.2.2 Seeding

Wildrice seed was harvested during September, 1981, from Bellows Bay on the Ottawa River (45°47'N 76°45'W) near the village of Westmeath, Ontario. It was considered to be of one population genotype and was selected for the robustness of the well tillered plants and for the high number of pistillate florets per panicle (mean 65.8) for the region. The seeds were kept wet until sown or submerged for winter storage. Seed which was overwintered was placed into perforated polyethylene bags, which in turn were placed into woven polypropylene seed bags, wrapped with galvanized poultry netting to keep out animals and again covered with a seed bag. These were sunk for winter storage in Pretties Bay of Mississippi Lake which bears a stand of wildrice.

Wooden posts were placed in the sediment to mark the centre of each plot to be seeded and 12.5 kg of wildrice seed (wet and drained) were broadcast within a 10m radius of each post during September 16 and 17, 1981. On May 11 and 13, 1982, plots adjacent to these were sown with the overwintered seed.

The 10m radius was a convenient distance for the scattering of seed by hand while motoring in circles while tethered to the stake and to limit habitat variation within the area. The size of the plots and the high densities of seed used provided for loss by animal predation with sufficient plants remaining for sampling.

4.2.3 Plant Sampling

The success of germination at seeded stations was determined by sampling the density of developing plants and the density of residual seed at McCullochs Mud Lake and Purdons Mud Lake. Plant density was sampled on June 8 (day 159) when the plants were at the late submerged to early floating leaf stage by suspending a $1/4m^2$ quadrat on top of the sediment and counting the number of plants in the quadrat (occasionally a $1/16m^2$ quadrat was used when plant densities were extremely high). Quadrat samples were made at one metre intervals (metres 1 to 10) along each of two radii chosen without bias from the centre of the plot and at approximately 180^0 from each other. The density of residual seed was obtained on June 14 (day 165) by dredging with an Eckman Dredge ($.0523m^2$) at 1,3,5,7,9 metres along one radius of each plot in McCullochs Mud Lake and Purdons Mud Lake. Seeds were retained on a 1.0mm soil sieve fitted to a floating styrofoam pail, classified as to condition (intact seed, germinated seed, empty hull or fragment) and whole seeds re-

tained. Ungerminated seeds were later tested for viability with a tetrazolium solution (.05% 2,3,5-triphenyl tetrazolium chloride in phosphate buffer pH 6.7). Although this test was found to be definitive for fresh seed, there were difficulties in classifying seeds recovered after extended periods in the sediment.

The performance of plants was recorded in terms of stem density, number of tillers, plant dry weight and the number of pistillate floret scars per panicle. At each station four quadrats $1/4m^2$ were constructed without bias at either end and on either side of a canoe using wooden laths. The number of stems in each quadrat was recorded. The number of tillers on five plants at each station was recorded. Ten plants were chosen without bias and carefully uprooted. Their roots were washed and the plants placed into paper bags. At a few sites where they were exceptionally large, only five plants were collected. All plants were dried at approximately 85°C and weighed. Twenty inflorescences were collected without bias at each station and the number of pistillate floret scars recorded.

4.2.4 Environmental Sampling

The habitat parameters measured were described in Chapter III. The ability of each of these to characterize littoral sites in a broad, one-time survey has been discussed.

4.3 RESULTS

4.3.1 Plant Performance

At the first observation in the middle of May, most of the fall seeded plots were well filled with a high density of wildrice plants at the submerged leaf stage. At Haley Lake the plants in the deeper plot near the centre of the lake exhibited much more growth and much higher density than those in shallow plots. The area of the deep plot was reported by local residents to be spring fed and often ice free for part of the winter.

The results of plant density measurements and seed dredging indicated good germination at the fall seeded plots (81.4%) and poor germination at the spring seeded plots (33.7%). The number of viable or questionable seed recovered from the spring seeded plots were higher than from the fall seeded plots.

The density of plants in the fall seeded plots at McCullochs Mud Lake varied from 26 to 182 plants per square metre (mean 94.5). In the spring seeded plots 7 to 93 plants per square metre (mean 44.0) were recorded. The fall seeded plots with low plant density at the submerged and floating leaf stages also had few remaining ungerminated seeds (correlation 0.88, n=6). Plants were present outside some seeded areas and along adjacent shoreline where no wildrice had been observed the previous season. Some factor such as ice

movement was responsible for the removal of much of the seed from some plots.

At the floating leaf and early aerial leaf stage it became apparent that the plants were stressed at all plots except for one pair at the mouth of the inlet to Haley Lake. Initially growth of the plants stalled and anthocyanin production increased. The plants which were stressed lost their older leaves and eventually supported only one leaf. Finally, the remaining leaf, usually a floating leaf, would become chlorotic with numerous void cells and by July the plants had all but disappeared. This occurred at the time that the seed resources were almost deleted. Careful observation revealed no significant predation or disease.

At the two successful plots in Haley Lake (HA05F and HA05S) the plants grew to approach the stature of the plants at the original stand at Bellows Bay.

One station at McCullochs Mud Lake (MC07X) and one station at Haley Lake (HA04Y) were added to the sampling regime, these being situated along the shore where some plants were scattered and no plants had been observed the previous season. It is assumed that the plants grew from seed displaced from some of the seeded plots.

4.3.1.1 Plant Performance

The growth of the plants at the various stations ranged from very limited to very robust. The plants at 'poor' sites were scattered, bore as few as a mean of 7.5 pistillate florets per panicle, and were very short with no tillers. These were mainly in lakes commonly termed 'mud lakes', which would only support wildrice near some shores or at the mouths of creeks. At the other extreme were sites such as Bellows Bay which supports extremely robust plants throughout most of its area. These plants were well tillered when isolated (about 15 tillers per plant), but within the stand where the stem density ranged from means of 121 to 160 stems/m^2, a mean of 3.7 tillers per plant was recorded. These plants often produced more than 100 pistillate florets per panicle (maximum 160 recorded), the average recorded being 63 per panicle. These robust plants produced much darker green pigmentation, wider leaves and stouter stems than those at other, more limited sites. The stature and density of the plants was so great as to prevent the movement of canoes or airboats into the stand at maturity.

The results for each station are given in Table 19. The density of stems was evenly distributed over the range, but the other variables were skewed to the lower end of the range. This was in part a result of more extensive sampling in the stands with limited plant development. Such sites were more abundant than sites that produced robust plants.

TABLE 19

Plant Performance Variables - Station Statistics

Station	Tillers per Plant	Stem Density (m2)	Pistillate Florets per Panicle	Plant Biomass (g/plant)	Plant Performance Score
Grassy Bay - Calabogie Lake (transects AA and BB) - natural stand					
AA000	0.70	93	11	1.60	-1.05
AA010	1.40	34	18	3.31	-0.63
AA020	0.60	140	8	1.27	-0.83
AA030	0.30	143	9	1.79	-0.77
AA040	0.20	26	17	1.49	-1.62
AA050	0.40	114	29	3.30	0.35
AA060	2.20	32	35	11.80	2.10
AA070	1.30	146	20	7.82	1.32
AA080	0.80	127	26	4.34	0.69
AA090	0.60	151	24	3.70	0.60
AA100	0.80	85	17	2.45	-0.61
AA110	1.10	89	21	5.17	0.24
BB010	0.70	72	14	3.63	-0.76
BB020	0.40	20	14	2.74	-1.54
BB030	0.40	53	10	2.44	-1.49
BB040	0.20	99	11	2.34	-1.06
BB050	0.30	70	10	1.82	-1.47
BB060	0.10	126	11	2.36	-0.83
BB070	0.40	167	19	2.96	0.29
BB080	0.40	50	8	1.80	-1.73
BB090	0.80	138	14	3.80	0.01
BB100	0.30	106	8	1.73	-1.25
BB110	0.10	100	8	1.10	-1.50
Bellows Bay - Ottawa River - natural stand (seed source)					
BE016	5.31	151	66	19.78	7.76
BE027	2.64	160	58	14.76	5.38
BE048	3.00	154	56	10.34	4.63
BE059	3.80	121	72	26.60	8.28
Rosedale Creek - Rideau River - natural stand??					
R001	18.4	03 est	71	95.2	10 +
Bennett Lake - northeast arm - seeded plots					
BN010	.	.	12	0.41	.
BN020	.	.	12	0.30	.
BN030	.	.	13	0.54	.
BN040	.	.	12	0.47	.
BN050	4.20	154	23	5.63	2.42
Haleys Lake - seeded plots					
HA01M	.	.	13	0.26	.
HA01S	.	.	13	0.26	.
HA02F	0.44	.	27	2.05	.
HA04F	0.70	4	17	0.66	.
HA04F	0.70	4	17	0.66	.
HA04S	.	.	8	0.16	.
HA04S	.	.	8	0.16	.
HA04Y	8.20	4	35	6.31	3.40
HA05F	4.20	114	55	14.92	5.45
HA05S	3.90	66	24	2.35	0.91
McCulloch Mud Lake - Mississippi River - seeded plots					
MC01F	0.50	.	10	0.30	.
MC02F	0.10	.	10	0.45	.
MC03F	.	.	.	0.29	.
MC03S	.	.	.	0.25	.
MC06F	1.20	.	17	1.68	.
MC07X	3.50	39	17	1.75	-0.01
Muskat Mud Lake - Muskrat River - natural stand					
MU010	7.20	120	38	16.70	6.07
Stafford Island - Mississippi River - natural stand					
ST010	4.00	172	13	2.40	.

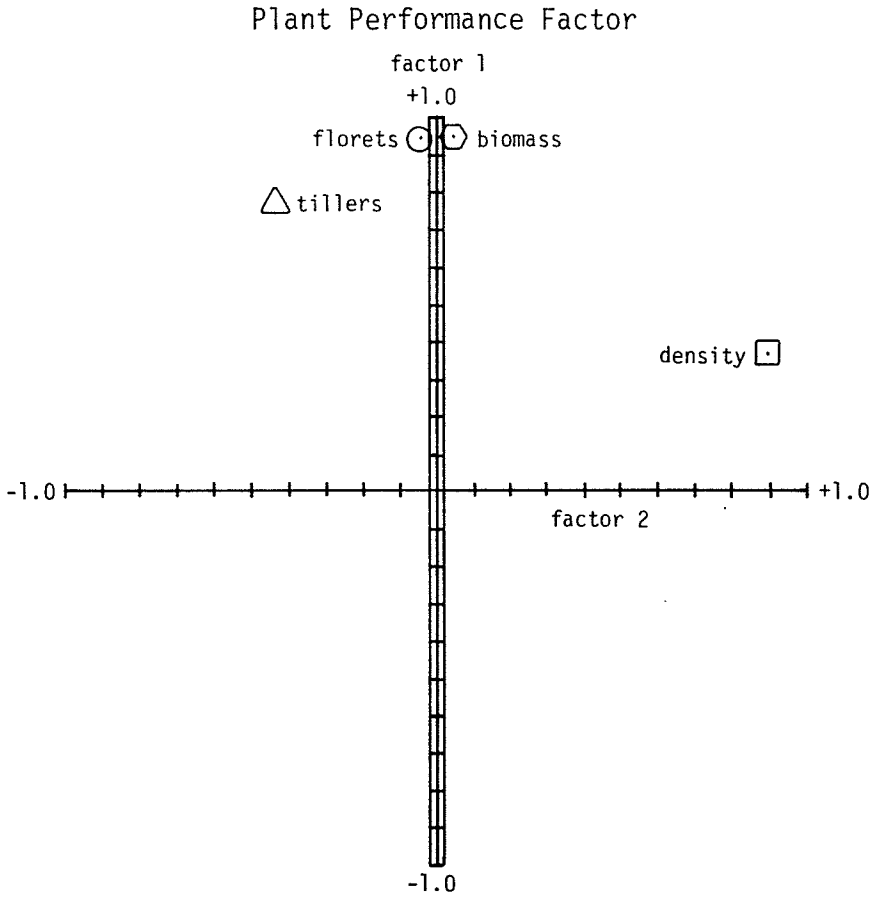
The dry weight of the plants is not considered a seed production characteristic, but is informative about the limitations to the plant and was correlated with the number of tillers per plant and particularly the number of florets produced per panicle (r=0.96, n=44). The plants with the greatest biomass were found to be well tillered and not crowded by other wildrice plants (eg. those at the periphery of a stand in shallow water). A maximum of 133g for one plant and a station mean of 95g were recorded under such conditions (station RO01). Where robust plants were within a stand, the biomass of the plants was reduced to around 18g per plant with few tillers but still with a high average of florets per panicle. The plants at most sites were much smaller averaging about 3g per plant. Severely limited plants from the same population as those at the upper end of the ranges had dry weights of less than 1g with no tillers and less than 10 florets per panicle.

4.3.1.2 Plant Performance Factor

A composite measure of plant performance was developed by means of factor analysis procedure (SAS - proc FACTOR). Stations with incomplete plant data or representing river locations were excluded. The primary factor (Figure 34) accounted for 64% of the variance of all plant performance variables. This factor was weighted primarily with the number of pistillate florets per head and the biomass of the

plants (r^2=0.95, n=33 for both), and secondarily with the number of tillers per plant (r^2=0.77, n=33). The weighting with stem density was less (r^2=0.38, n=33).

Figure 34: Plant Performance Factor - Relationship Amongst Plant Variables



Scores for each sample station were generated (SAS - proc SCORE) using the standardized scoring coefficients of the principal components analysis (Table 20) and the station plant performance data (Table 19).

TABLE 20

Plant Performance Factor Scoring Coefficient

Sample Variable	Tillers n/plant	Density stem/m2	Florets n/panicle	Biomass g/plant
Mean	1.83	96.21	24.65	5.85
Standard Deviation	2.12	49.76	17.81	6.23
Number	33	33	33	33
Standardized Scoring Coeff.	0.3031	0.1467	0.3732	0.3721

Note: Station scores are the total of the products of the standardized scoring coefficient and the variable values standardized to the mean and standard deviation given above.

4.3.2 Discriminant Model of Plant Success

The stations sampled could be separated into two groups - those which supported wildrice plants which grew to maturity, and those in which the plants died. A discriminant model was developed which would segregate these two groups and, by inference, indicate possible controlling parameters.

The variables used in the analysis were the sediment nutrient variables, the mean water depth after yearday 200, sediment lab conductivity and pH, and sediment bulk density and loss-on-ignition. Water variables were not used since their seasonal and profile variations were significantly erratic and the ability of water variables to discriminate sites was found to be poor (Chapter III). Since some stations were sampled on more than one occassion, each data record for each station was considered a separate sample. Some samples with outlier values for some variables were removed from the analysis. Such outliers were considered possible deviants (possible analysis errors) and did not contribute

to the development of a robust model which, according to the objectives of the model, would represent the majority of the cases.

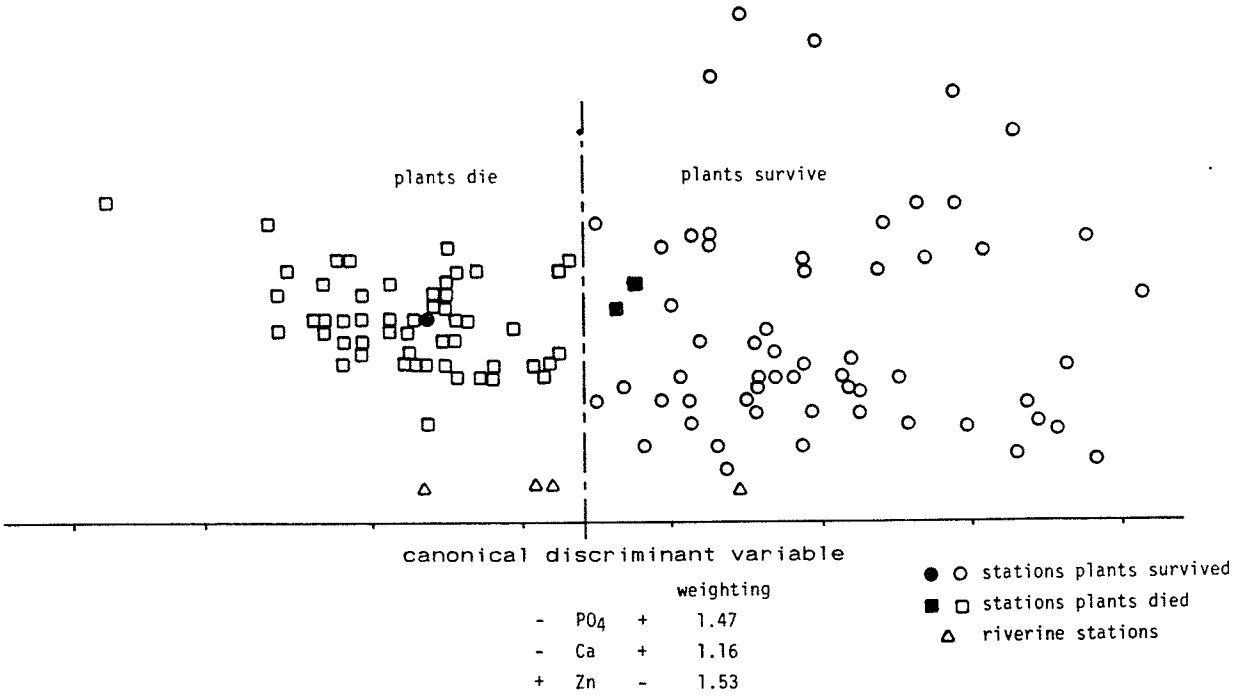
Stepwise discriminant analysis (SAS - proc STEPDISC) was used to eliminate some variables based upon their lack of significance in discriminating the two groups of sites. The remaining variables, significant at the 1% level, were sediment phosphate (F=77), zinc (F=58), calcium (F=28), potassium (F=17) and manganese (F=12).

To simplify the model further a series of discriminant analyses were run (SAS - proc DISC) eliminating the least significant variable in each case. The models generated were used to classify the original samples and the misclassified samples evaluated to give a measure of the degree of success of the model. The variables sediment phosphate, zinc and calcium gave the most efficient discrimination with the least number or misclassifications.

A final model, illustrated in Figure 35, was generated using canonical variables. The samples from the riverine sites were removed as these were consistently misclassified and would affect the final model. Only the first canonical variable was significant.

A graphic analysis of the variables shows that both phosphate and calcium values were lower at the unsuccessful stations. The negative relationship for zinc was required to

Figure 35: Discriminant Model of Wildrice Plant Success/Failure



discriminate between the unsuccessful and successful sites at the lower end of the nutrient range. The sites with the best plant performance were still higher in zinc than the unsuccessful sites while the sites with poor plant performance were the lowest in the range of zinc.

4.3.3 Plant Performance Model

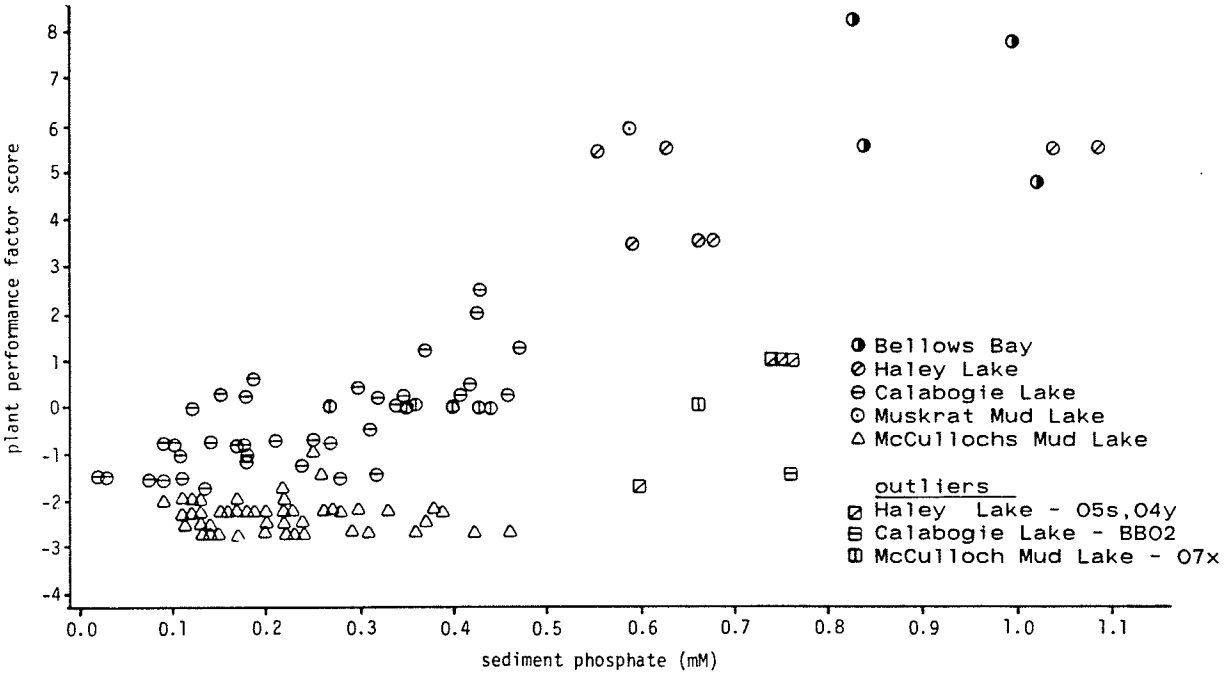
The survey data were used to develop a multivariate model for Z. palustris plant performance based on stable habitat parameters.

Initially all sediment nutrient parameters, sediment lab pH and conductivity, and loss-on-ignition, and water depth were considered. Linear regressions of all subsets of these

variables with the plant performance factors for all stations indicated that little was to be gained by the inclusion of more than two variables. The first of these was phosphate because of its high correlation with plant performance ($r=0.77$, $n=63$)(Figure 36). Loss-on-ignition was not used since a graphic analysis indicated it was biased by the condition of a few stations at the extreme high range of plant performance and sites at the lower end were incorrectly ranked. The best alternatives for the model were phosphate and one of the micronutrients, iron or manganese, which were correlated. The better model was achieved with manganese. The only reasonable choice for a third variable was calcium concentration, but the gain was minimal and was not used in order to simplify the model. The model developed using sediment phosphate and manganese had the advantage that stations at which the plants died were correctly ranked below those with poor plant performance.

Outlier stations were identified based on residual distances and each case was considered for its validity to the model and reasons for inconsistent values for plant performance. For example, station HA05S (adjacent to station HA05F, a very successful plot) was found to have a low performance value. This was a result of the plants in the plot having been clipped by animals (presumably muskrat), thus hindering their final development and making sampling difficult. Low values for plant biomass and number of florets were recorded

Figure 36: Plant Performance Relationship to Sediment Phosphate



for this station despite observations that the plants had potentials similar to those in the adjacent plot. Such stations biasing the model were deleted from the data set. Two other records which had sediment phosphorous values inconsistent with other replicates were also deleted. Outliers were deleted only for these reasons.

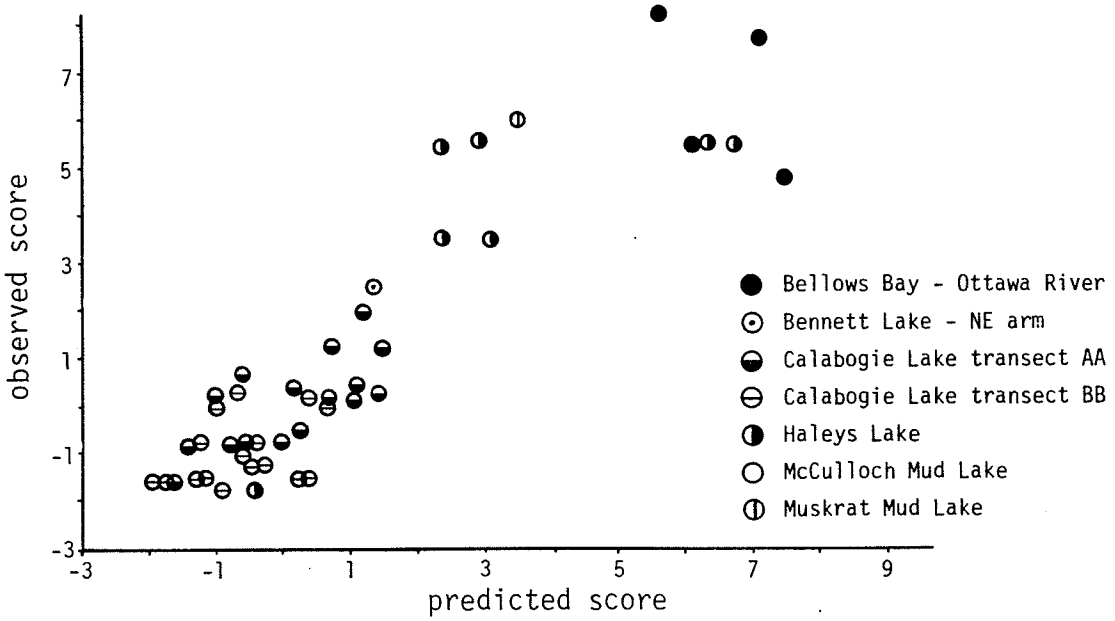
The predictability of the final model is illustrated in Figure 37 which illustrates the relationship between predicted plant performance scores and those developed from observed plant performance. The model itself is given as:

plant performance factor = -2.31 + 7.84 x sed. PO_4 + 2.35 x sed. Mn

(r^2=0.819 n=50)

The stations with several records of environmental parameters were correctly predicted close to one another and several stations within similar sites were likewise predicted to have similar plant performance. The ranks of stations within sites were reasonably predicted. The degree of predictability decreased at the high end of the range, a result of increasing variance of both plant and environmental variables within sites and stations at the higher levels. The stations which did not support wildrice had extremely low predicted scores.

Figure 37: Plant Performance Model - Relationship Between Observed and Predicted Plant Performance



Phosphate contributed most to the model accounting for 80% of the variance. Manganese explained another 1% of the

variance and the remaining 19% is attributed to other variables, random variation and sampling error.

4.4 DISCUSSION

Both the discriminant model for wildrice plant success and the regression model for plant performance provided realistic ordinations of sample sites based upon sediment nutrient variables, in particular phosphate concentrations. Predicted scores for replicate samples from stations sampled on different dates were similar and dissimilar sites had distinctly different predicted scores. This indicated that these habitat variables were sufficiently discriminating to permit one-time sampling of sites and still provide reasonable predictions of plant performance.

It is not suggested that either model is static or definitive for plant performance in the region. Such models can remain flexible and be easily refined as more data becomes available.

One objective of the models was to infer the habitat characteristics which relate best to fruit production. In both models sediment phosphorous concentration was overwhelmingly the most significant variable. The persistent inclusion of micronutrients was also considered significant. The poor performance or death of plants at stations with low sediment nutrient concentrations indicated that many sites

in the region were too nutrient deficient to warrant introduction of wildrice.

It was noteworthy that neither the primary habitat factor (calcium and magnesium concentrations), nor sediment phosphate was the most effective variable for the discrimination of sites (Chapter III). Also, sediment loss on ignition, which was the primary discriminator for sites, was not useful in predicting plant performance at the lower end of the performance scale. This illustrates that site discrimination does not imply a relationship to plant performance.

The plant performance factor well represented the plant performance as observed in the field. The strong weighting with the number of pistillate florets per panicle and the number of tillers per plant well represents the seed production characteristics of the plants at any station. The strong weighting with plant biomass well represents the growth opportunity provided by the habitat. The low level of weighting with stem density is considered realistic since the density of plants is subject to many physical parameters not easily sampled or quantifiable and not directly related to plant growth once the plant has become established. This is supported by the lack of correlation between numbers of tillers per plant and stem densities (r^2=0.01, n=33).

The plant performance model may be applied directly to littoral, lacustrine sites in eastern Ontario as long as

site conditions are within the ranges sampled and analyses made using the same methods. The actual values for the plant variables are not directly predictable; however, they may be indirectly predicted by assuming the mean values of all the stations in the model which fall within the confidence limits for the predicted plant performance score. For example, a sampled station at Rosedale Creek on the Rideau River was predicted to have a plant performance score of 8.30 with 95% confidence limits of 4.4 to 11.7. The mean values for all stations in the model within these limits were:

	mean	std. dev.
tillers/plant	4.3	1.33
pistillate florets/panicle	56.7	9.2
biomass (g/plant)	16.4	4.5

These would be reasonable estimates for seed production characteristics and plant biomass if similar genotypes were introduced to this station. Useful stand density predictions are not possible with this model since the plant peformance factor poorly represented density. It also does not predict the outcome of Z. palustris growth when physical conditions, nutrient conditions and perturbations are outside the ranges of the variables used in the model.

The overwintering of seed by the method used appeared to have extended the dormancy period. Upon recovery from storage, many of the seeds around the periphery of the bags had

germinated whereas those in the middle had not. Chemical dormancy factors may become concentrated in the centres of the bags whereas at the periphery they may leach out or be changed by exposure to the sediment (Cardwell, Oelke & Elliott, 1978). It is suggested that germination of stored seed may be promoted if the seed is not closely confined but permitted exposure to sediment conditions or flowing water.

SUMMARY AND CONCLUSIONS

The first chapter of this thesis provides a quantitative description of fruit production in commercially useful stands of Zizania palustris in eastern Ontario. Measurements of stem and panicle density, pistillate floret number and fruit dry weight are given as well as estimates of the proportions of developed and predated fruit and the proportions available for harvest. The proportion actually harvested was very dependent upon harvest effort. The degree of predation by Apamea apamiformis larvae was quantified and varied considerably between stands, contributing substantially to a reduction in harvestable fruit.

Stands could not be considered homogeneous areas. The concepts of gross and net stand area and harvestable net area were introduced.

By growing plants from six sources in the greenhouse, it was indicated that more gain in fruit production was to be made by breeding superior plants than collecting seed from superior stands without selection. Plant variation was greater than the depth variation within the depth range tested, but response to depth differed between sources, indicating useful adaptations. The influence of nutrient

availability was more significant than both water depth and genetic potential in determining the quantity of fruit produced. The genetic potential of the plant limits the number and size of fruit which may be produced and the water depth over 70cm influenced the number of tillers produced. The nutrient regime of the habitat influenced the number of tillers and florets produced within genetic and depth limitations.

The ranges and dynamics of selected water and sediment physical and chemical parameters were described. These were evaluated for their ability to discriminate littoral sites if data were collected on a one-time survey basis. Sediment characteristics, in particular loss-on-ignition and sediment micro-nutrients, were considered the most useful variables.

Models were developed to predict and identify the causes of Z. palustris plant survival and plant performance in terms of biomass, tiller number and floret number. Sediment phosphate concentration was the most important variable and sediment minor nutrients were persistently indicated for inclusion in the models.

This study provides the first documentation of Z. palustris plant failure. The failures were attributed to a lack of plant nutrients in highly organic littoral sediments.

The data collected in this and other similar studies must be viewed with caution. Often specific study areas were

heavily sampled and thus the sample distribution is biased by the number of samples taken at each site. To reduce this bias, the means of sites were often used so that each site or station had equal weighting. This limits the amount of inference which can be drawn from the data. For most variables, both plant and habitat, the variances were dependent upon the means. Insufficient data was collected at the higher values to permit tranformations to remove this dependency.

5.1 FURTHER RESEARCH

The major plant nutrient, sulfur, was conspicuous by its absence in this and other studies (Lee, 1982-1984). Until suitable methods for the sampling of sulfur in littoral sediments with high organic matter are developed, any models of plant response will be incomplete and possibly erroneous. Sulfur was not determined because it could not be proven that the methods tried (interstitial water dialysis sampling (Hesslein, 1976, Smith & Klug, 1981) and specific ion potentiometry (Allam et al.,1972 ; Hseu & Rechnitz, 1968)) successfully detected sulfide at the concentrations and in the types of sediments encountered.

At the pH and redox potentials documented, sulfur should be predominantly in the form of hydrogen sulfide gas. All the methods available have the common problems of how to prevent rapid oxidation of samples and the evolution of gas

when samples are brought to the surface, thereby reducing pressure. Interstitial water dialysis sampling appears to provide the most realistic method since it permits rapid, on-site analysis and has been used for profundal sampling (Cook, 1981; Smith and Klug, 1981). It has the disadvantage of requiring the samplers to be left in place for many days. Analyses for total sulfur or acid volatile sulfur are also possible if bulk samples are quickly treated to trap the sulfide or raise the pH, but such methods would measure forms of sulfur unavailable to the plant. Sulfate has been found in measurable concentrations in profundal sediments by Cook (1981) and Smith and Klug (1981).

The apparent lack of plant response to sediment ammonium concentrations opens the question of whether the method used correctly represented the availability of nitrogen to the plant. The method was taken from Lee (1982) who initially tested for nitrate and ammonium in extracted samples, but found nitrate concentrations to be negligible (Lee, pers. comm.) as is expected at the pH and redox potentials encountered. However, Atkins (pers. comm.) has been able to measure nitrate in filtered interstitial water of similar sediments. It is evident that these methods require further testing to determine how well they correlate with plant development.

The assumption that the values obtained using the extractants are reasonable indications of the actual availabili-

ties of nutrients to plants, is also required for the other nutrients sampled. Since some correlations with plant growth were obtained (Chapter IV) this assumption must be correct to some extent.

The effect of freezing sediment samples for storage and the changes this causes (as indicated in Chapter III) is of concern. The changes to plant nutrient concentrations caused by this methods must be researched if we are to have confidence in the data.

Future work using ionic displacement extractants should use vacuum filtration to reduce the variance caused by the time of extraction. The total volume of water in the system can be assumed to be the volume of the filtrate which could be made up to a constant volume (eg 100ml) using deionized water. In this manner the total amount of ions extracted could be assumed to be contained in the final volume, neglecting the small proportion remaining in the solid phase and filter paper which could be washed with deionized water. Samples should be selected at random for each batch so that variation amongst batches becomes a random variable which is not correlated with sample date or sample site.

Bulk sampling of soils may be satisfactory for the testing of nutrient availability for rooted plants, but it does little to describe the distribution and dynamics of sediment nutrients. A study is needed using sediment profile sampling to describe the vertical and horizontal distributions of

nutrients in littoral sediments and the overlying water, and their dynamics.

The actual nutrient requirements of Zizania spp. have not been researched. The hypothesis that wildrice derives all or part of its nutrition through its submerged leaves in the early stages of its life cycle also requires testing. Growth under controlled conditions is required; the most useful method being liquid culture. Nutrient mediums for the growth of Zizania and a system permitting the use of nutrients in their reduced form are required before studies of nutrient limitations, nutrient acquisition physiology and utilization can begin. Considering the great influence of nutrient availability on fruit production and the frequency of nutrient limitations identified by this study and those of Lee, such techniques are urgently needed.

The resources available did not permit the sampling of fruit weight at the specific sampling stations. Further research of this nature should include this variable to determine if there are relationships between habitat and seed size.

This thesis has described both genotypic and environmental variations affecting the fruit production of Z. palustris. If tests of plant response to the environment are to be made, some assurance of genetic similarity amongst test plants is needed. The trials described in Chapter IV met this requirement by using a single population as seed

source, although other populations were included in the models. Further testing should be conducted using this same population which appears to be a good producer.

Similarly, if plant traits are to be tested, consistent environmental conditions should be used. These conditions should be standardized by those undertaking such research and they should approach optimal conditions for the plants' development so that the full potential of the genotypes can be expressed. This obviously was not the case in this study since some populations performed better in the field than in the greenhouse.

Testing of habitat and genotypes is complicated in that specific genotypes may respond differently to different habitat conditions as was demonstrated in the tank trials described in Chapter II. A good evaluation of a genotype should include its response to varying nutrient conditions within the range of natural conditions; varying water depth, including depths greater than 1m; and varying substrate physical properties.

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Appendix A

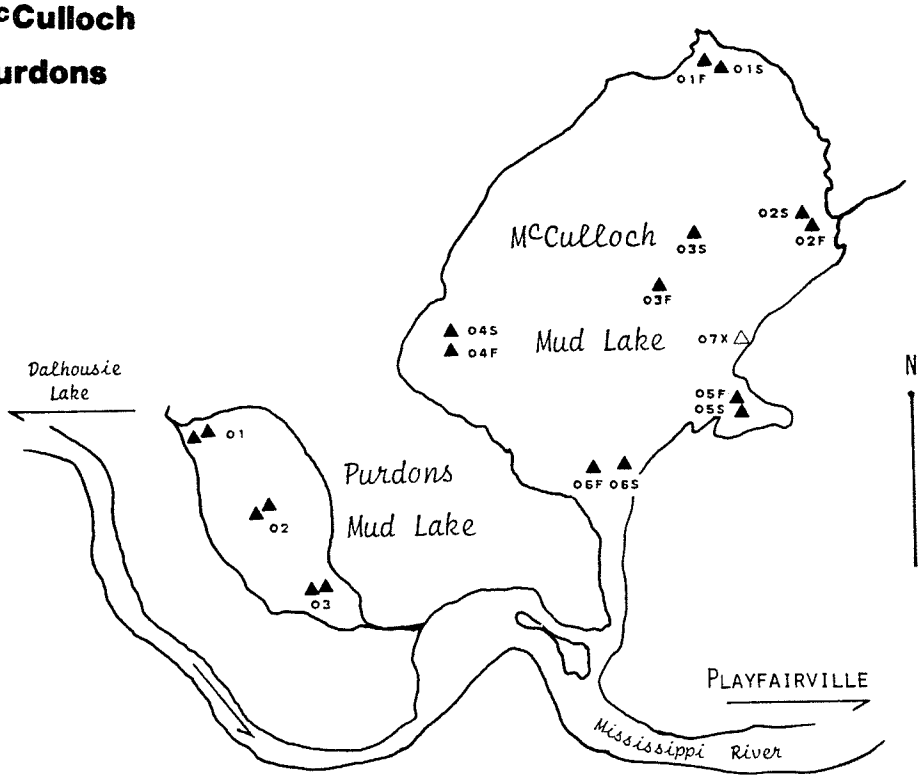
SAMPLE SITES AND STATIONS - EASTERN ONTARIO

Study Site Locations

code	site name	map/ref.	lat/long
BE	Bellows Bay, Ottawa River	31F/15 520723	76.54W 45.47N
BN	Bennett Lake - NE arm (Fall River)	31C/16 870767	76.26W 44.56N
CL	Grassy Bay, Calabogie Lake	31F/7 660150	76.43W 45.17N
CA			
AA	- transect A		
BB	- transect B		
CB	Code Bay, Mississippi Lake	31F/1 073937	76.10W 45.06N
EM	Easton Marsh, Rideau River	31B/13 297676	76.54W 46.52N
HA	Haley Lake	31F/1 000875	76.16W 45.02N
IR	Irish Creek, Rideau River	31B/13 270662	76.56W 44.51N
KB	Kings Bay, Mississippi Lake	31F/1 075920	76.10W 45.05N
MC	McCullochs Mud Lake	31C/16 825813	76.29W 44.59N
ML	Mud Lake, Ardoch, Mississippi R.	31C/15 520790	76.53W 44.57N
MU	(Muskrat) Mud Lake, Muskrat River	31F/11 420663	77.02W 45.44N
NO	Norris Lake, Manitoba Interlake		
OT	Ottawa River at Bonnechere River	------ ------	76.34W 45.29N
PB	Pretties Bay, Mississippi Lake	31F/1 074891	76.11W 45.03N
PL	Pine Lake, Manitoba Interlake		
PU	Purdons Mud Lake, Mississippi R.	31C/16 817807	76.30W 44.58N
RO	Rideau River at Rosedale Creek	31B/13 253708	76.57W 44.53N
SP	Sprague Lake, Manitoba SE		
ST	Stafford Island, Mississippi River	31F/1 970871	76.19W 45.02N

McCulloch

Purdons



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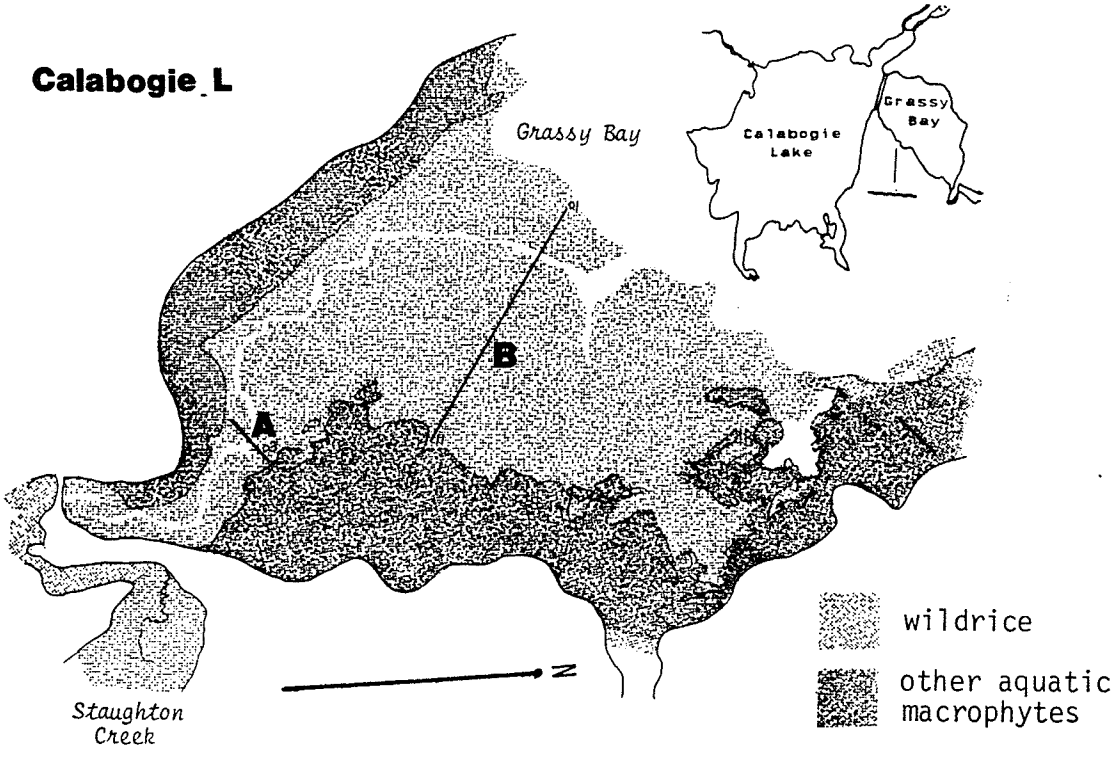
Calabogie L



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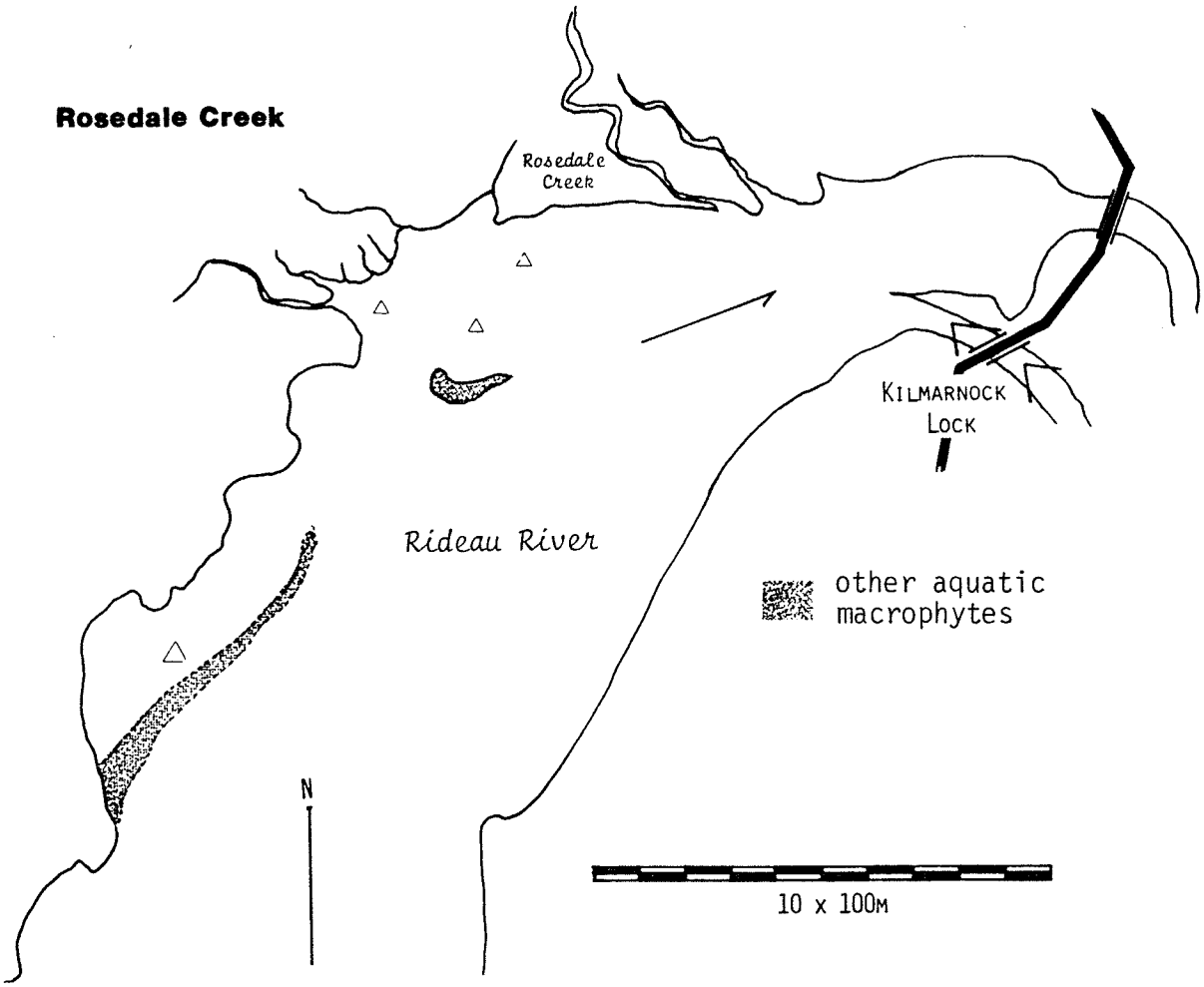
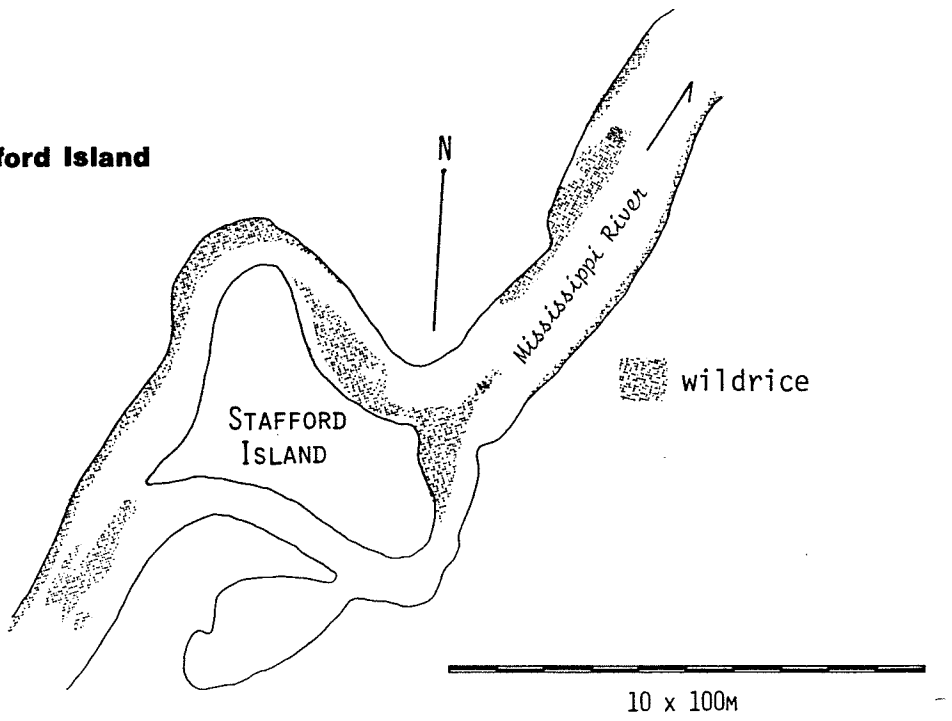
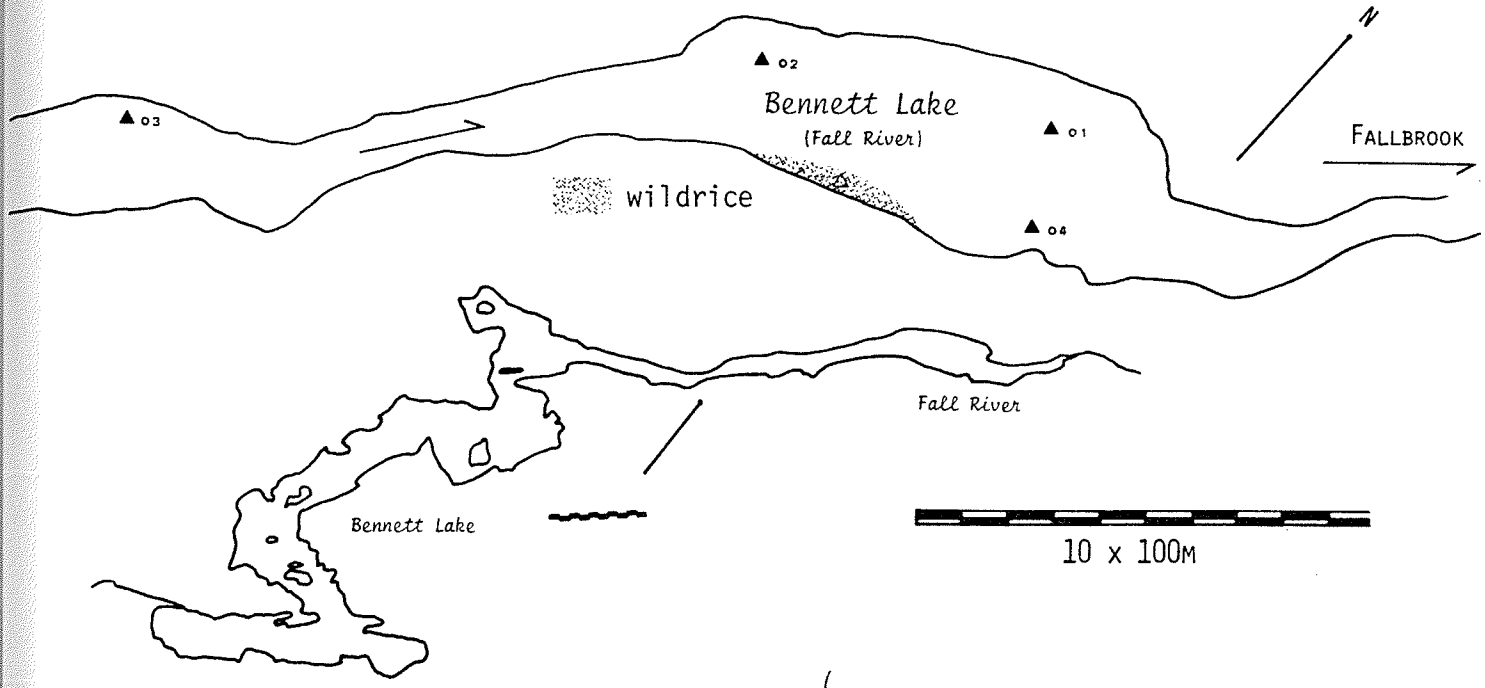
Rosedale Creek



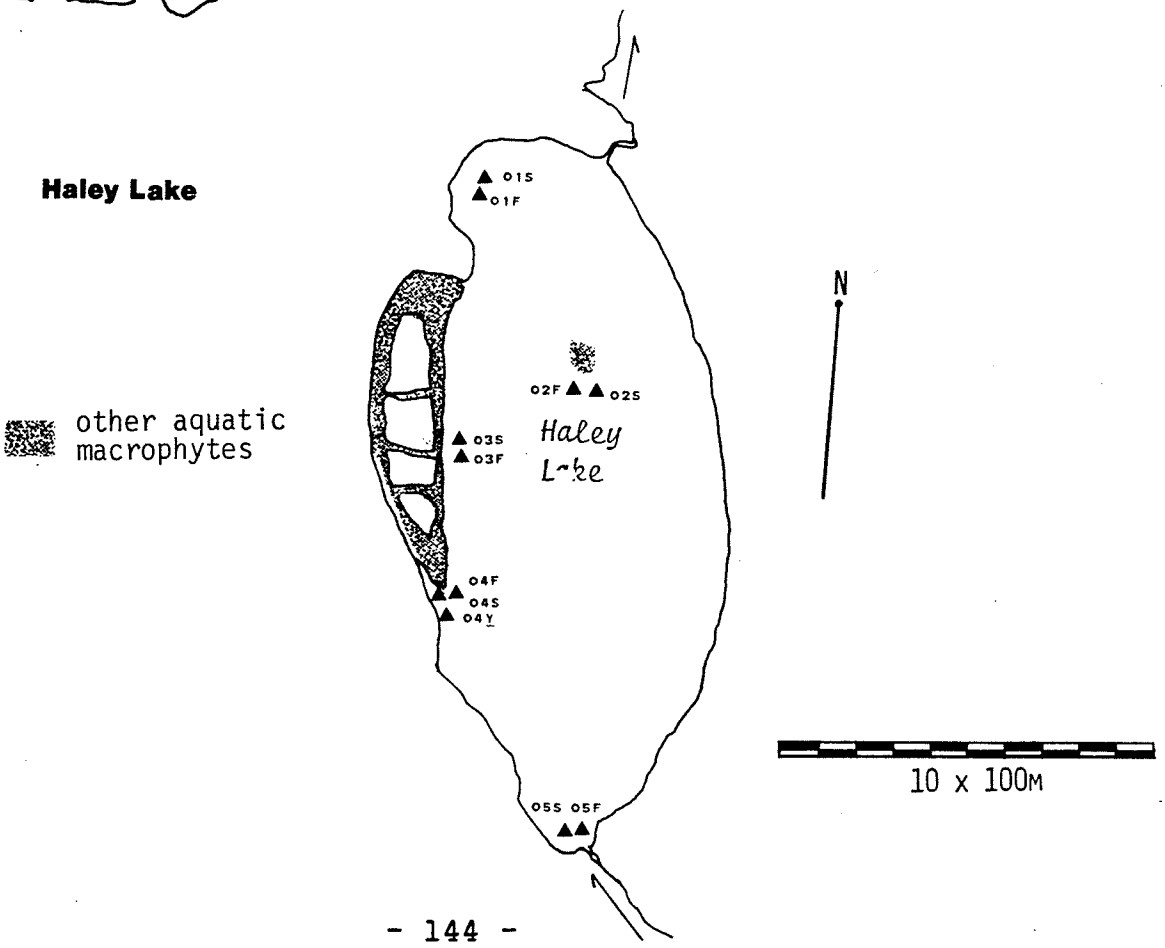
Stafford Island



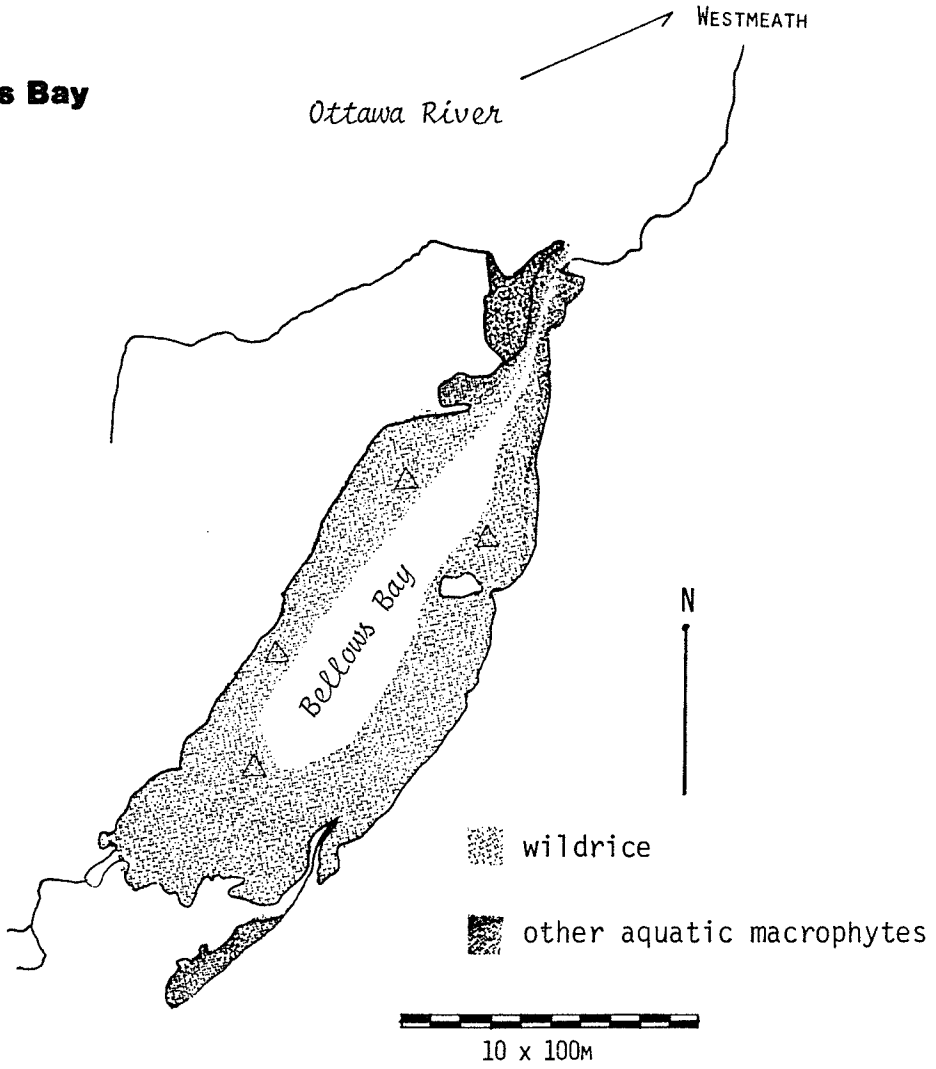
Bennett



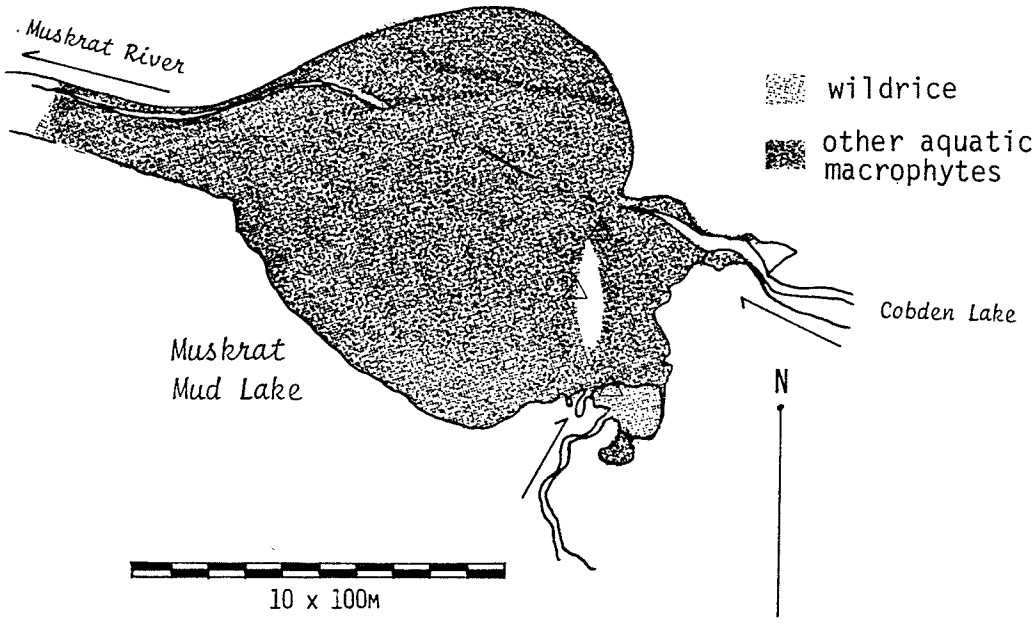
Haley Lake



Bellows Bay



Muskrat Mud Lake



Appendix B SAMPLE DATA

WATER PHYSICAL PARAMETERS (and sed. field cond.) - Eastern Ontario littoral stations - 1980-1982

site	station	yearday	year	water depth (cm)	temperature (C)	dissolved oxygen (mg/ml)	pH	water redox (mV)	water conductivity (uS)	sediment field conductivity (uS)
AA	000	224	82	50	16.5	.	7.20	180	235	377
	000	230	82	.	20.5	.	7.60	115	260	.
	000	240	82	50	14.0	.	7.50	215	213	389
	000	245	82	.	17.0	.	.	212	204	.
	010	207	82	40	24.0	9.80	7.90	135	255	.
	010	211	82	40	22.0	8.40	.	.	245	.
	010	211	82	80	20.0	6.30	.	.	240	.
	010	218	82	25	19.0	8.50	7.00	150	235	.
	010	224	82	40	16.2	.	7.30	180	240	380
	010	230	82	.	20.0	.	7.70	150	288	.
	010	240	82	48	14.0	.	7.60	210	210	389
	010	245	82	.	15.0	.	.	245	216	.
	020	207	82	65	24.4	8.40	7.60	150	250	.
	020	211	82	54	20.0	8.60	.	.	240	.
	020	218	82	30	20.0	10.20	7.20	135	240	.
	020	224	82	48	16.2	.	7.30	160	240	426
	020	230	82	.	20.5	.	7.60	150	270	.
	020	240	82	58	15.0	.	7.55	215	215	385
	020	245	82	.	17.0	.	.	220	228	.
	030	207	82	70	24.0	8.50	7.00	130	250	.
	030	211	82	51	20.0	8.50	.	.	240	.
	030	218	82	50	20.0	9.90	7.30	155	250	.
	030	224	82	52	16.2	.	7.30	170	238	426
	030	230	82	.	21.0	.	7.60	155	270	.
	030	240	82	52	15.0	.	7.55	215	218	362
	030	245	82	.	17.0	.	.	230	232	.
	040	207	82	67	24.0	8.30	7.50	135	255	.
	040	211	82	63	21.0	7.50	.	.	245	.
	040	218	82	50	20.0	8.30	7.20	180	240	.
	040	224	82	80	16.2	.	7.10	175	238	451
	040	230	82	.	20.5	.	7.50	170	270	.
	040	240	82	88	15.0	.	7.60	220	219	405
	040	245	82	.	17.0	.	.	230	236	.
	050	207	82	65	23.5	7.55	7.50	130	250	.
	050	211	82	51	20.0	8.00	.	.	235	.
	050	218	82	55	19.5	8.90	7.30	140	240	.
	050	224	82	55	16.0	.	7.10	175	239	398
	050	230	82	.	21.0	.	7.30	170	270	.
	050	240	82	60	15.0	.	7.55	220	221	379
	050	245	82	.	17.0	.	.	215	233	.
	060	207	82	100	21.0	6.40	7.70	130	250	.
	060	211	82	83	19.0	7.80	.	.	230	.
	060	218	82	85	18.0	8.00	7.00	140	230	.
	060	224	82	85	16.3	.	7.00	160	241	450
	060	230	82	.	20.5	.	7.15	170	265	.
	060	240	82	95	15.0	.	7.50	220	221	482
	060	245	82	.	15.0	.	.	207	233	.
	070	207	82	98	22.0	7.80	7.45	140	255	.
	070	211	82	50	21.0	7.85	.	.	230	.
	070	218	82	50	17.0	8.10	7.00	100	235	.
	070	224	82	60	16.2	.	7.10	160	238	353
	070	230	82	.	21.0	.	7.30	165	268	.
	070	240	82	72	15.0	.	7.30	210	226	350
	070	245	82	.	17.0	.	.	230	236	.
	080	207	82	60	22.4	7.80	7.50	145	255	.
	080	211	82	48	20.0	7.80	.	.	240	.
	080	218	82	50	20.0	7.90	7.20	155	235	.
	080	224	82	60	15.5	.	7.10	160	238	370
	080	230	82	.	20.6	.	7.30	175	268	.
	080	240	82	65	15.0	.	7.30	210	225	353
	080	245	82	.	16.0	.	.	.	233	.
	090	207	82	70	22.0	7.90	7.50	140	250	.
	090	211	82	53	20.0	8.30	.	.	240	.
	090	218	82	55	17.5	8.50	7.20	150	240	.
	090	224	82	55	15.5	.	7.00	160	238	365
	090	230	82	.	20.5	.	7.30	180	268	.
	090	240	82	70	15.0	.	7.30	215	228	354
	090	245	82	.	16.0	.	.	.	231	.
	100	207	82	60	23.0	8.50	7.30	140	255	.
	100	218	82	55	20.0	8.20	6.80	110	240	.
	100	224	82	60	16.2	.	7.10	160	240	384
	100	230	82	.	20.5	.	7.30	185	269	.
	100	240	82	70	15.5	.	7.30	215	230	389
	100	245	82	.	16.0	.	.	.	232	.
	110	207	82	45	24.4	8.70	7.80	130	250	.
	110	211	82	50	20.0	7.75	.	.	240	.
	110	218	82	50	17.0	8.80	7.30	140	235	.
	110	224	82	53	16.2	.	.	.	241	392
	110	230	82	.	20.5	.	7.35	180	271	.
	110	240	82	60	15.5	.	7.40	210	230	387
	110	245	82	.	16.0	.	.	.	232	.
BB	010	207	82	115	22.1	5.80	7.10	100	135	.
	010	211	82	112	19.5	6.80	.	.	130	.
	010	218	82	120	19.0	8.30	6.80	90	130	.
	010	224	82	108	16.0	.	7.30	105	102	287
	010	230	82	106	19.2	.	7.50	150	118	275
	010	240	82	.	15.0	.	7.50	200	100	.
	010	245	82	110	16.5	.	7.30	190	110	240
	020	207	82	110	22.0	7.40	6.90	100	130	.
	020	211	82	135	20.0	8.50	.	.	125	.
	020	218	82	140	19.0	9.10	7.10	90	130	.
	020	224	82	133	16.3	.	7.80	120	105	304
	020	230	82	131	20.0	.	7.50	145	117	316
	020	240	82	.	15.0	.	7.50	200	97	.
	020	245	82	133	15.5	.	7.20	205	115	286
	030	207	82	100	22.0	6.70	7.10	120	140	.
	030	211	82	108	20.0	7.90	.	.	130	.
	030	218	82	120	19.0	8.90	7.30	90	130	.
	030	224	82	105	15.8	.	7.60	140	107	291
	030	230	82	106	20.0	.	7.35	140	118	321

WATER PHYSICAL PARAMETERS (and sed. field cond.) - Eastern Ontario littoral stations - 1980-1982

site	station	yearday	year	water depth (cm)	temperature (C)	dissolved oxygen (mg/ml)	pH	water redox (mV)	water conductivity (uS)	sediment field conductivity (uS)
BB	030	240	82	.	16.0	.	7.50	205	98	.
	030	245	82	108	15.5	.	7.10	210	111	280
	040	224	82	102	16.1	.	7.50	140	113	398
	040	230	82	100	20.0	.	7.35	180	121	354
	040	240	82	.	15.0	.	7.50	205	100	.
	040	245	82	100	16.5	.	6.90	210	114	282
	050	207	82	100	22.0	7.00	6.80	110	150	.
	050	211	82	100	20.0	8.00	.	.	135	.
	050	218	82	115	18.5	8.60	7.30	90	130	.
	050	224	82	105	16.1	.	7.40	140	122	332
	050	230	82	102	20.4	.	7.40	170	123	325
	050	240	82	.	15.0	.	7.45	210	106	.
	050	245	82	105	16.5	.	7.10	215	122	298
	060	207	82	90	22.2	6.80	6.90	80	160	.
	060	211	82	90	20.0	7.80	.	.	135	.
	060	218	82	100	19.0	9.00	7.30	110	140	.
	060	224	82	82	16.8	.	7.50	140	137	386
	060	230	82	77	20.1	.	7.40	170	148	322
	060	240	82	.	15.0	.	7.40	210	108	.
	060	245	82	85	17.0	.	7.10	225	138	329
	070	207	82	65	22.7	6.85	7.20	100	170	.
	070	211	82	55	21.0	7.30	.	.	150	.
	070	218	82	50	18.5	8.20	7.20	110	140	.
	070	224	82	53	16.8	.	7.50	140	166	230
	070	230	82	73	20.2	.	7.50	180	164	215
	070	240	82	.	15.0	.	7.45	212	118	.
	070	245	82	72	17.0	.	6.90	230	149	216
	080	207	82	75	22.0	7.50	7.10	80	255	.
	080	211	82	75	21.5	8.50	.	.	185	.
	080	218	82	100	19.0	9.30	7.30	110	160	.
	080	224	82	75	16.3	.	7.70	160	198	400
	080	230	82	80	20.4	.	7.50	180	210	454
	080	240	82	.	15.0	.	7.55	210	139	.
	080	245	82	85	17.0	.	7.10	230	159	393
	090	207	82	65	22.0	6.90	7.35	100	260	.
	090	211	82	69	20.0	7.20	.	.	230	.
	090	218	82	50	19.0	8.60	7.30	130	190	.
	090	224	82	70	16.6	.	7.50	155	206	447
	090	230	82	72	21.5	.	7.55	180	228	439
	090	240	82	.	15.0	.	7.55	210	161	.
	090	245	82	75	17.0	.	.	220	176	401
	100	207	82	60	23.0	7.35	6.90	110	280	.
	100	211	82	65	20.0	7.30	.	.	285	.
	100	218	82	45	21.0	8.30	7.20	130	240	.
	100	224	82	62	16.6	.	7.70	160	221	488
	100	230	82	61	20.0	.	7.60	185	248	489
	100	240	82	.	15.0	.	7.65	210	186	.
	100	245	82	67	17.0	.	.	230	198	467
	110	207	82	40	23.5	7.45	7.30	100	310	.
	110	211	82	55	21.0	8.50	.	.	270	.
	110	218	82	40	19.5	8.00	7.30	130	270	.
	110	224	82	50	17.1	.	7.70	165	253	458
	110	230	82	42	20.0	.	7.70	170	273	388
	110	240	82	.	15.0	.	7.65	205	200	.
	110	245	82	50	17.0	.	.	230	219	393
BE	060	229	82	24	19.5	.	8.10	150	262	432
	070	229	82	42	19.5	.	7.30	160	305	510
	080	229	82	45	20.5	.	8.25	160	303	475
	090	229	82	33	20.0	.	7.60	155	352	489
BN	010	243	82	75	15.0	.	8.45	190	185	367
	020	243	82	71	16.0	.	8.30	160	161	529
	030	243	82	78	15.0	.	8.30	145	165	376
	040	243	82	73	17.0	.	8.45	190	153	366
	05X	243	82	52	15.0	.	8.20	185	172	405
HA	01F	231	82	30	19.0	.	8.50	150	225	516
	01M	231	82	31	20.0	.	8.60	160	218	473
	01S	231	82	30	18.5	.	8.60	160	225	510
	02F	231	82	45	.	.	.	.	.	.
	03F	231	82	58	19.0	.	.	.	236	461
	03F	246	82	55	.	.	.	.	.	.
	04F	246	82	38	.	.	.	.	.	.
	04S	231	82	38	20.0	.	8.50	175	255	504
	04S	246	82	35	.	.	.	.	.	.
	04Y	231	82	23	21.0	.	8.70	150	256	493
	04Y	246	82	25	.	.	.	.	.	.
	05F	231	82	43	19.0	.	8.40	170	257	406
	05F	246	82	36	.	.	.	.	.	.
	05S	231	82	38	19.0	.	8.40	170	255	500
	05S	246	82	32	.	.	.	.	.	.
MU	010	250	82	20	12.0	.	.	.	290	806
	020	250	82	62	13.0	.	8.50	155	175	808
	030	250	82	55	13.0	.	8.40	140	178	508
	040	250	82	38	16.0	.	8.40	140	187	437
PL	010	313	82	25	3.0	.	6.70	.	550	1029
	020	313	82	53	3.0	.	6.50	.	480	1150
	030	313	82	58	2.0	.	6.50	.	460	954
	040	313	82	98	2.0	.	6.70	.	440	841
	050	313	82	62	2.0	.	6.60	.	450	1029
RD	010	251	82	88	13.0	.	8.10	140	135	408
	020	251	82	40	16.0	.	6.90	160	159	500
	030	251	82	80	15.0	.	7.90	150	138	435
	040	251	82	43	15.0	.	8.30	160	139	698
ST	010	223	82	50	19.8	7.40	6.10	110	147	254
	020	223	82	40	20.2	10.10	6.50	90	139	249
	030	223	82	67	20.0	9.00	6.20	130	142	246
	040	223	82	.	19.4	6.80	6.10	150	143	371

WATER PHYSICAL PARAMETERS (and sed. field cond.) - Eastern Ontario littoral stations - 1980-1982

site	station	yearday	year	water depth (cm)	temperature (C)	dissolved oxygen (mg/ml)	pH	water redox (mV)	water conductivity (uS)	sediment field conductivity (uS)
MC	01F	206	82	18	20.2	8.80	8.00	115	273	.
	01F	210	82	20	23.0	9.50	8.20	100	285	.
	01F	217	82	20	25.0	10.50	.	.	310	.
	01F	225	82	18	13.0	.	8.70	150	282	540
	01F	232	82	20	18.0	.	8.50	180	265	488
	01F	241	82	23	17.0	.	8.85	180	233	442
	01F	247	82	18	15.5	.	.	.	225	478
	01S	206	82	18	20.3	8.70	7.90	115	285	.
	01S	210	82	20	23.0	9.50	8.20	120	280	.
	01S	217	82	30	24.0	9.80	.	.	310	.
	01S	225	82	19	16.0	.	8.70	150	262	529
	01S	232	82	25	18.0	.	8.80	180	258	464
	01S	241	82	25	18.0	.	8.70	180	230	456
	01S	247	82	21	15.0	.	.	.	230	448
	02F	206	82	28	20.5	7.40	7.55	140	312	.
	02F	210	82	30	20.0	8.95	8.20	130	280	.
	02F	217	82	25	24.0	10.50	.	.	295	.
	02F	225	82	19	18.8	.	8.70	180	275	463
	02F	232	82	23	18.0	.	8.50	170	260	480
	02F	241	82	22	16.0	.	8.55	180	230	420
	02F	247	82	22	15.0	.	.	.	225	448
	02S	206	82	32	21.0	7.40	7.90	145	305	.
	02S	210	82	31	20.0	8.40	7.80	120	280	.
	02S	217	82	30	21.0	9.50	.	.	295	.
	02S	225	82	29	19.0	.	8.60	150	275	465
	02S	232	82	30	18.0	.	8.60	170	259	468
	02S	241	82	33	15.0	.	8.50	175	231	482
	02S	247	82	30	15.5	.	.	.	225	438
	03F	206	82	55	20.6	7.40	8.20	140	290	.
	03F	210	82	60	19.5	8.90	8.20	110	270	.
	03F	217	82	55	21.0	9.80	.	.	275	.
	03F	225	82	54	18.2	.	8.70	150	270	429
	03F	232	82	55	18.0	.	8.50	160	254	395
	03F	241	82	56	16.0	.	8.70	170	210	403
	03F	247	82	53	14.0	.	.	.	225	407
	03S	206	82	49	21.0	8.10	7.90	145	300	.
	03S	210	82	50	18.5	8.70	7.80	110	270	.
	03S	217	82	50	21.5	9.50	.	.	270	.
	03S	225	82	52	18.0	.	8.80	180	260	415
	03S	232	82	52	18.0	.	8.40	160	245	407
	03S	241	82	55	16.0	.	8.70	170	218	403
	03S	247	82	50	14.5	.	.	.	220	414
	04F	206	82	51	21.2	7.60	7.90	121	298	.
	04F	210	82	54	21.0	8.50	8.20	100	260	.
	04F	217	82	55	23.0	9.50	.	.	290	.
	04F	225	82	45	18.4	.	8.40	180	254	384
	04F	232	82	48	19.0	.	8.30	170	253	413
	04F	241	82	50	16.0	.	8.35	180	211	403
	04F	247	82	46	16.5	.	.	.	230	410
	04S	206	82	45	21.2	7.10	7.75	115	301	.
	04S	210	82	50	21.0	8.20	7.30	110	265	.
	04S	217	82	50	24.0	10.50	.	.	290	.
	04S	225	82	46	17.7	.	8.25	115	257	431
	04S	232	82	48	20.0	.	8.40	160	249	415
	04S	241	82	49	17.0	.	8.30	170	211	376
	04S	247	82	48	16.5	.	.	.	225	448
	05F	206	82	20	21.7	8.20	8.20	150	300	.
	05F	210	82	27	19.0	8.20	7.80	100	275	.
	05F	217	82	23	23.5	9.80	.	.	280	.
	05F	225	82	17	22.2	.	8.80	180	278	458
	05F	232	82	19	19.0	.	8.50	180	263	449
	05F	241	82	22	16.0	.	8.70	175	220	470
	05F	247	82	19	16.0	.	.	.	240	479
	05S	206	82	20	21.6	8.30	8.20	150	300	.
	05S	210	82	19	19.0	8.50	7.75	110	275	.
	05S	217	82	21	23.5	8.70	.	.	275	.
	05S	225	82	20	19.4	.	8.70	160	262	441
	05S	232	82	21	19.5	.	8.40	180	269	432
	05S	241	82	23	16.0	.	8.70	175	228	470
	05S	247	82	18	16.0	.	.	.	235	445
	06F	206	82	48	21.6	7.60	8.20	155	210	.
	06F	210	82	51	18.0	8.20	7.90	95	260	.
	06F	217	82	51	20.0	8.80	.	.	250	.
	06F	225	82	58	19.8	.	8.50	180	237	425
	06F	232	82	45	19.0	.	8.40	170	255	382
	06F	241	82	53	17.0	.	8.80	180	218	401
	06F	247	82	49	17.0	.	.	.	225	418
	06S	206	82	.	21.3	7.90	8.25	135	283	.
	06S	210	82	40	18.0	8.20	8.35	85	270	.
	06S	217	82	45	20.0	8.80	.	.	250	.
	06S	225	82	42	20.4	.	8.80	130	260	415
	06S	232	82	40	19.0	.	8.40	180	263	413
	06S	241	82	47	17.0	.	8.70	175	219	401
	06S	247	82	43	16.5	.	.	.	235	405
	07X	206	82	35	21.0	7.20	7.75	150	300	.
	07X	210	82	40	18.0	8.20	8.20	130	270	.
	07X	217	82	38	21.0	8.80	.	.	285	.
	07X	225	82	36	19.2	.	8.70	160	269	505
	07X	232	82	40	18.0	.	8.30	180	265	496
	07X	241	82	40	16.0	.	8.60	175	220	495
	07X	247	82	39	15.0	.	.	.	225	499
	08Y	232	82	20	18.0	.	7.85	180	315	464

WATER NUTRIENT VARIABLES - Eastern Ontario littoral stations - 1981-1982

site=AA

station number	yearday	lab number	water potassium (uM)	water calcium (uM)	water magnesium (uM)	water zinc (uM)
030	141	1	38.1	1123	977	0.24
030	147	2	30.4	948	595	0.24
030	154	3	24.8	929	480	0.23
030	161	4	14.1	917	471	0.23
030	166	5	4.9	979	480	0.26
030	168	6	10.0	904	450	0.24
030	175	7	3.8	842	399	0.18
030	183	8	13.8	879	420	0.37
030	207	9	4.3	1004	471	0.26
030	211	10	4.6	992	459	0.31
030	218	11	5.4	1073	476	0.26
030	224	12	4.1	1123	480	0.18
030	230	13	5.9	1148	484	0.15
030	240	14	6.6	1098	459	0.11
030	245	15	6.8	1180	437	0.14

site=BB

010	141	16	33.2	786	288	0.14
010	147	17	26.3	642	195	0.14
010	154	18	22.5	549	169	0.14
010	161	19	21.7	586	218	0.11
010	168	21	21.2	561	182	0.11
010	175	22	16.4	767	301	0.09
010	183	23	20.7	699	246	0.14
010	196	24	15.6	823	305	0.12
010	207	25	15.9	624	203	0.11
010	211	26	14.6	555	182	0.11
010	218	27	16.1	555	178	0.17
010	224	28	15.1	493	176	0.08
010	230	29	15.1	493	161	0.14
010	240	30	15.1	455	139	0.11
010	245	31	15.1	505	178	0.06
110	141	32	31.7	1010	450	0.15
110	147	33	26.3	767	314	0.14
110	154	34	21.2	792	339	0.17
110	161	20	18.4	898	374	0.14
110	168	35	28.2	836	369	0.15
110	175	36	13.8	917	386	0.12
110	196	37	17.4	1180	573	0.14
110	207	38	11.3	1204	573	0.15
110	211	39	10.5	1180	543	0.14
110	218	40	9.7	1148	552	0.20
110	224	41	10.7	1117	561	0.14
110	230	42	12.3	1092	514	0.12
110	240	43	13.3	929	420	0.15
110	245	44	13.0	998	459	0.14

site=BE

000	229	78	36.8	1148	586	0.12

site=BN

000	243	75	28.9	736	259	0.09
010	173	71	29.2	749	250	0.11
020	173	72	29.2	761	283	0.12
030	173	73	27.6	780	258	0.12
040	173	74	28.9	717	250	0.09

WATER NUTRIENT VARIABLES - Eastern Ontario littoral stations

site=HA

station number	yearday	lab number	water potassium (uM)	water calcium (uM)	water magnesium (uM)	water zinc (uM)
01S	148	61	39.9	904	369	0.15
02F	174	63	37.9	929	399	0.09
02S	148	62	40.4	911	374	0.09
020	231	64	44.8	1035	557	0.09
03F	152	66	40.2	904	386	0.12
03S	148	65	40.2	892	382	0.11
04F	152	68	41.2	998	459	0.14
04S	174	67	36.6	1028	492	0.14
05S	174	69	23.0	1085	480	0.14
05S	181	70	32.0	1291	531	0.14

site=MC

010	139	45	28.8	1035	358	0.17
020	139	46	28.8	1210	429	0.21
03F	138	47	29.4	792	305	0.17
03S	148	51	29.7	1104	376	0.20
03S	153	52	26.9	1198	408	0.14
03S	160	53	26.8	1235	418	0.14
03S	176	54	21.5	1291	463	0.09
03S	210	55	23.0	1241	531	0.09
03S	217	56	23.0	1204	573	0.09
03S	232	58	24.8	1173	585	0.09
03S	241	59	22.3	1085	518	0.15
03S	247	60	21.7	1110	480	0.14
030	225	57	24.6	1166	543	0.11
040	139	48	30.4	948	310	0.18
050	139	49	28.6	1035	348	0.17
060	139	50	28.1	1079	382	0.14

site=MU

030	250	82	45.8	724	343	0.11

site=PU

01F	166	83	36.6	873	259	0.12
02F	166	85	34.8	742	216	0.15
03F	166	84	34.5	749	220	0.09

site=RO

030	251	79	5.1	818	280	0.09

site=ST

0A0	223	76	22.3	618	165	0.14
0B0	223	77	21.5	611	185	0.08

SEDIMENT NUTRIENT, PHYSICAL AND INDICATOR VARIABLES - Eastern Ontario littoral stations - 1980-1982

site station	lab number	sediment ammonium (mm)	sediment phosphate (mm)	sediment potassium (mm)	sediment calcium (mm)	sediment magnesium (mm)	sediment iron (mm)
AA010	129	0.52	0.181	0.118	10.8	2.0	0.482
AA010	173	0.88	0.208	0.119	13.3	2.5	0.900
AA020	130	0.79	0.180	0.151	12.8	2.4	0.684
AA030	131	0.44	0.093	0.102	33.5	5.6	0.593
AA030	174	1.30	0.274	0.115	19.8	3.7	0.523
AA040	132	0.51	0.074	0.088	18.1	3.1	0.648
AA050	133	0.52	0.414	0.114	11.2	2.0	0.796
AA050	175	1.69	0.457	0.150	7.3	1.5	0.698
AA060	134	0.83	0.429	0.161	11.2	2.2	0.823
AA070	135	0.46	0.368	0.112	11.7	2.2	0.817
AA070	177	1.72	0.471	0.119	7.4	1.5	0.884
AA080	136	0.45	0.192	0.096	14.3	2.6	0.921
AA090	137	0.77	0.302	0.122	10.1	1.9	1.214
AA090	178	1.65	0.419	0.121	8.5	1.9	0.579
AA100	138	0.83	0.311	0.114	16.8	2.9	0.928
AA110	139	0.49	0.145	0.086	19.7	3.3	0.814
AA110	179	1.72	0.349	0.108	9.0	1.7	0.635
BB010	42	0.36	0.104	0.080	12.2	1.8	0.693
BB010	17	0.51	0.174	0.133	32.7	5.0	1.719
BB020	43	0.27	0.086	0.126	29.8	4.7	0.891
BB020	18	2.25	0.756	0.335	15.3	2.7	1.153
BB030	45	0.75	0.034	0.090	24.6	3.4	1.379
BB030	19	0.85	0.018	0.059	18.5	4.9	0.821
BB040	20	0.80	0.183	0.129	20.3	3.0	0.814
BB050	46	0.71	0.074	0.109	36.4	5.9	1.245
BB050	21	1.27	0.114	0.092	23.9	3.3	1.146
BB060	47	1.04	0.252	0.104	24.8	3.7	0.976
BB060	22	1.22	0.140	0.082	33.4	4.9	1.040
BB070	48	1.23	0.176	0.087	16.0	2.7	0.287
BB070	23	0.88	0.322	0.095	13.6	2.3	0.325
BB080	49	1.55	0.139	0.098	33.8	5.3	1.082
BB080	24	1.57	0.136	0.087	26.2	4.1	1.408
BB090	50	1.05	0.123	0.083	28.0	4.4	1.040
BB090	25	1.45	0.338	0.085	15.8	2.5	0.849
BB100	52	1.65	0.185	0.125	33.6	5.3	1.578
BB100	27	1.24	0.236	0.102	22.1	3.5	0.580
BB110	53	0.95	0.278	0.070	35.0	5.8	0.962
BB110	28	1.34	0.320	0.095	20.3	3.5	0.644
BE016	75	1.92	1.003	0.514	26.9	6.0	13.85
BE027	76	1.61	0.844	0.505	38.7	5.9	18.42
BE048	77	2.21	1.020	0.562	30.2	5.6	18.98
BE059	78	2.42	0.832	0.480	28.3	5.8	11.95
BN010	99	0.87	0.114	0.117	2.5	1.2	0.381
BN020	100	2.73	0.374	0.324	3.5	1.3	1.047
BN030	101	2.11	0.302	0.258	5.8	1.4	0.686
BN040	102	2.04	0.245	0.219	4.0	1.3	0.534
BN050	103	1.23	0.426	0.129	7.4	1.8	0.471
HA01M	112	0.82	0.393	0.240	9.2	2.8	0.268
HA01S	105	1.25	0.378	0.288	17.7	3.7	0.287
HA02F	171	0.85	0.115	0.118	9.2	2.4	0.245
HA02F	106	1.10	0.254	0.201	21.1	4.7	0.308
HA03F	107	0.66	0.188	0.181	14.2	3.5	0.328
HA03F	119	0.83	0.223	0.169	13.1	3.4	0.356
HA04F	169	0.90	0.221	0.159	11.9	3.3	0.231
HA04F	120	1.15	0.598	0.488	12.1	3.8	0.238
HA04S	108	1.38	0.415	0.240	11.5	3.5	0.231
HA04S	118	1.19	0.464	0.298	10.6	3.2	0.266
HA04X	170	1.38	0.653	0.304	16.1	4.9	0.245
HA04Y	108	1.87	0.679	0.512	14.4	3.2	0.224
HA04Y	113	1.28	0.589	0.335	16.7	4.4	0.126
HA05F	172	2.21	1.045	0.391	27.5	6.2	0.398
HA05F	168	1.86	1.091	0.460	23.1	5.6	0.433
HA05F	111	1.13	0.553	0.236	14.9	3.9	0.175
HA05F	115	0.84	0.629	0.327	11.5	2.9	0.175
HA05S	167	1.15	0.740	0.326	20.2	4.4	0.245
HA05S	110	2.06	0.747	0.358	17.4	4.1	0.217
HA05S	114	1.01	0.756	0.531	13.8	3.6	0.308
MC01F	55	0.87	0.224	0.115	14.2	3.2	0.273
MC01F	30	0.73	0.198	0.133	11.0	2.8	0.301
MC01S	54	0.84	0.139	0.143	14.2	2.9	0.280
MC01S	29	0.88	0.132	0.131	9.6	2.4	0.224
MC02F	57	1.74	0.222	0.114	11.7	2.6	0.224

site station	sediment zinc (mm)	sediment manganese (mm)	loss on ignition (%)	sediment bulk density (g/cc)	sediment lab conductivity (us)	sediment lab ph
AA010	0.028	0.043	86.9	79.717	381	6.32
AA010	0.026	0.092	86.9	79.717	417	6.19
AA020	0.017	0.057	82.7	21.077	432	6.39
AA030	0.024	0.106	76.6	55.475	340	6.30
AA030	0.024	0.092	76.6	55.475	504	6.21
AA040	0.014	0.050	76.3	87.388	320	6.40
AA050	0.032	0.092	71.9	34.328	405	6.30
AA050	0.023	0.078	71.9	34.328	514	6.39
AA060	0.033	0.071	66.6	23.716	347	6.41
AA070	0.036	0.078	89.4	32.995	381	6.22
AA070	0.021	0.057	89.4	32.995	441	6.22
AA080	0.033	0.064	70.5	11.149	337	6.26
AA090	0.026	0.057	74.7	14.840	422	6.39
AA090	0.018	0.064	74.7	14.640	469	6.30
AA100	0.029	0.078	81.4	61.172	422	6.30
AA110	0.022	0.092	78.2	15.745	344	6.33
AA110	0.017	0.078	78.2	15.745	504	6.30
BB010	0.012	0.086	84.6	61.532	383	6.40
BB010	0.018	0.223	84.6	61.532	500	6.20
BB020	0.005	0.173	87.5	56.234	391	6.45
BB020	0.027	0.093	87.5	56.234	391	6.10
BB030	0.016	0.144	88.6	60.083	488	6.50
BB030	0.007	0.108	88.6	60.083	422	6.40
BB040	0.021	0.122	87.5	71.302	640	6.35
BB050	0.010	0.122	86.5	84.314	356	6.35
BB050	0.033	0.122	86.5	84.314	531	6.40
BB060	0.051	0.151	80.8	45.123	558	6.40
BB060	0.018	0.173	80.8	45.123	577	6.30
BB070	0.028	0.072	81.4	19.129	384	6.35
BB070	0.027	0.072	81.4	19.129	510	6.30
BB080	0.050	0.151	87.3	81.284	537	6.60
BB080	0.025	0.158	87.3	81.284	703	6.40
BB090	0.021	0.122	82.3	75.440	506	6.50
BB090	0.022	0.101	82.3	75.440	770	6.45
BB100	0.027	0.144	86.5	82.889	523	6.40
BB100	0.028	0.093	86.5	82.889	661	6.40
BB110	0.037	0.185	87.8	41.115	461	6.40
BB110	0.025	0.088	87.8	41.115	682	6.30
BE016	0.159	0.678	9.6	217.871	874	6.35
BE027	0.183	0.809	13.4	144.780	881	6.35
BE048	0.139	0.747	19.9	56.182	892	6.30
BE059	0.145	0.589	18.3	152.882	794	6.35
BN010	0.018	0.120	75.3	23.799	413	6.40
BN020	0.042	0.225	70.3	25.148	744	6.05
BN030	0.054	0.189	77.9	29.074	695	6.30
BN040	0.040	0.113	70.1	28.835	591	6.20
BN050	0.083	0.148	74.0	25.119	500	6.20
HA01M	0.068	0.050	87.1	45.051	553	6.40
HA01S	0.077	0.057	66.8	45.4046	591	6.45
HA02F	0.063	0.071	89.2	28.2879	480	6.95
HA02F	0.063	0.071	89.2	28.2879	556	6.50
HA03F	0.044	0.142	67.7	33.1207	459	6.70
HA03F	0.044	0.107	67.7	33.1207	479	6.70
HA04F	0.061	0.043	84.1	39.0077	521	6.92
HA04F	0.065	0.028	84.1	39.0077	523	6.51
HA04S	0.064	0.036	85.6	37.8966	587	6.38
HA04S	0.056	0.036	85.6	37.8966	615	6.48
HA04X	0.081	0.043	89.5	35.4813	587	6.85
HA04Y	0.050	0.050	89.5	35.4813	723	6.30
HA04Y	0.051	0.050	89.5	35.4813	526	6.57
HA05F	0.122	0.220	71.8	48.4005	583	6.71
HA05F	0.093	0.220	71.8	48.4005	594	6.54
HA05F	0.071	0.128	71.8	48.4005	520	6.50
HA05F	0.054	0.156	71.8	48.4005	508	6.50
HA05S	0.070	0.156	70.2	35.8344	521	6.80
HA05S	0.069	0.107	70.2	35.8344	653	6.40
HA05S	0.048	0.170	70.2	35.8344	582	6.52
MC01F	0.066	0.043	67.1	31.8860	663	6.70
MC01F	0.061	0.028	67.1	31.8860	774	6.70
MC01S	0.061	0.036	66.0	32.6024	740	6.70
MC01S	0.053	0.021	66.0	32.6024	791	6.70
MC02F	0.078	0.028	88.2	28.1222	804	6.55

SEDIMENT NUTRIENT, PHYSICAL AND INDICATOR VARIABLES - Eastern Ontario littoral stations - 1980-1982

site station	lab number	sediment ammonium (mm)	sediment phosphate (mm)	sediment potassium (mm)	sediment calcium (mm)	sediment magnesium (mm)	sediment iron (mm)
MC02F	32	0.80	0.135	0.193	9.8	2.3	0.349
MC02S	142	0.78	0.165	0.124	12.8	2.6	0.238
MC02S	185	1.20	0.129	0.226	14.7	2.8	0.545
MC02S	151	1.13	0.134	0.209	12.1	2.3	0.510
MC02S	153	1.43	0.221	0.203	16.7	3.2	0.489
MC02S	156	2.51	0.227	0.209	17.2	3.5	0.482
MC02S	123	1.18	0.240	0.218	12.4	2.5	0.405
MC02S	56	1.08	0.289	0.124	14.0	3.0	0.231
MC02S	124	1.05	0.201	0.209	10.6	2.2	0.370
MC02S	125	0.87	0.147	0.188	11.4	2.3	0.328
MC02S	31	0.73	0.137	0.188	10.6	2.3	0.384
MC03F	58	1.07	0.132	0.127	11.5	2.4	0.285
MC03F	34	0.85	0.094	0.121	8.7	2.2	0.237
MC03S	59	0.89	0.120	0.090	10.2	2.2	0.187
MC03S	33	1.03	0.111	0.107	11.7	2.4	0.209
MC04F	61	1.03	0.128	0.084	12.2	2.6	0.202
MC04F	36	1.27	0.112	0.127	8.7	1.9	0.348
MC04S	60	1.10	0.107	0.127	11.7	2.4	0.348
MC04S	35	1.49	0.134	0.124	10.4	2.3	0.313
MC05F	144	0.74	0.204	0.099	12.6	2.8	0.255
MC05F	159	1.41	0.325	0.215	17.1	3.5	0.666
MC05F	162	1.29	0.282	0.199	16.4	3.4	0.446
MC05F	160	1.15	0.184	0.167	14.7	2.8	0.638
MC05F	161	1.00	0.198	0.185	16.8	3.5	0.489
MC05F	163	0.88	0.172	0.112	30.2	2.6	0.276
MC05F	146	1.15	0.284	0.149	10.8	2.6	0.333
MC05F	63	1.24	0.229	0.105	16.2	3.5	0.326
MC05F	147	1.11	0.219	0.129	12.2	2.7	0.376
MC05F	38	1.51	0.161	0.185	10.8	2.5	0.354
MC05S	64	1.65	0.224	0.119	16.0	3.5	0.376
MC05S	37	1.42	0.190	0.129	11.7	2.7	0.390
MC06F	66	1.39	0.281	0.111	11.4	2.4	0.328
MC06F	40	1.05	0.264	0.109	10.1	2.2	0.273
MC06S	141	0.88	0.198	0.099	8.7	2.0	0.210
MC06S	158	0.89	0.200	0.179	17.0	3.5	0.468
MC06S	157	1.45	0.151	0.133	12.8	2.7	0.335
MC06S	154	0.81	0.155	0.134	12.9	2.6	0.370
MC06S	186	0.57	0.188	0.145	11.4	2.5	0.196
MC06S	145	0.76	0.183	0.133	10.5	2.1	0.315
MC06S	65	1.70	0.173	0.136	11.7	2.4	0.315
MC06S	150	0.53	0.265	0.114	10.6	2.3	0.315
MC06S	148	0.61	0.186	0.117	10.6	2.3	0.342
MC06S	39	0.41	0.118	0.173	11.0	2.2	0.538
MC07X	143	1.29	0.356	0.121	17.5	3.5	0.281
MC07X	155	1.20	0.352	0.110	29.4	5.4	0.713
MC07X	126	0.76	0.428	0.124	23.6	4.2	0.785
MC07X	67	2.14	0.443	0.147	19.9	3.7	0.526
MC07X	127	0.74	0.660	0.153	27.6	4.7	1.001
MC07X	128	0.89	0.395	0.133	22.7	4.0	0.799
MC07X	41	1.15	0.266	0.115	23.8	4.3	0.619
MC08Y	149	0.65	0.526	0.154	13.2	2.6	0.347
MU010	81	2.15	0.587	0.819	24.9	4.0	9.160
MU020	79	3.44	0.917	0.587	33.0	3.0	2.847
MU030	82	2.49	0.751	0.408	12.6	2.4	1.226
MU040	83	2.76	0.817	0.595	17.5	2.6	1.613
PU02F	121	1.95	0.380	0.272	15.0	2.6	0.948
PU03S	122	2.97	0.307	0.204	11.2	2.0	0.775
RD010	88	2.72	0.858	0.353	27.4	5.4	4.774
RD020	89	1.95	1.021	0.749	40.1	10.2	6.503
RD030	90	2.88	0.068	0.398	30.9	6.1	1.895
RD040	91	2.74	0.779	0.349	38.9	7.4	6.300
ST010	84	2.02	0.868	0.380	16.2	3.2	10.38
ST020	85	1.41	0.506	0.218	15.1	2.9	4.764
ST030	86	1.67	0.559	0.218	14.9	2.8	6.983
ST040	87	1.33	0.576	0.125	11.1	1.7	11.94

site station	sediment zinc (mm)	sediment manganese (mm)	loss on ignition (%)	sediment bulk density (g/cc)	sediment conductivity (us)	lab sediment ph
MC02F	0.057	0.014	88.2	28.1222	928	6.80
MC02S	0.052	0.043	89.1	29.3799	521	6.48
MC02S	0.070	0.043	89.1	29.3799	504	6.71
MC02S	0.068	0.028	89.1	29.3799	504	6.80
MC02S	0.087	0.036	89.1	29.3799	591	6.59
MC02S	0.103	0.064	89.1	29.3799	507	6.91
MC02S	0.062	0.043	89.1	29.3799	651	6.41
MC02S	0.073	0.043	89.1	29.3799	635	6.50
MC02S	0.051	0.021	89.1	29.3799	595	6.33
MC02S	0.041	0.021	89.1	29.3799	543	6.40
MC02S	0.044	0.028	89.1	29.3799	802	6.85
MC03F	0.058	0.028	85.1	20.2488	586	6.80
MC03F	0.051	0.028	85.1	20.2488	760	6.85
MC03S	0.046	0.021	86.0	26.2936	551	6.85
MC03S	0.062	0.021	86.0	26.2936	888	6.70
MC04F	0.046	0.028	89.5	26.0946	530	6.85
MC04F	0.050	0.021	89.5	26.0946	763	6.55
MC04S	0.042	0.035	88.8	28.9201	593	6.80
MC04S	0.059	0.021	88.8	28.9201	738	6.50
MC05F	0.041	0.029	84.4	35.7479	525	6.56
MC05F	0.087	0.043	84.4	35.7479	500	6.80
MC05F	0.079	0.036	84.4	35.7479	528	6.88
MC05F	0.087	0.043	84.4	35.7479	448	6.66
MC05F	0.078	0.043	84.4	35.7479	459	6.88
MC05F	0.044	0.022	84.4	35.748	400	6.91
MC05F	0.058	0.022	84.4	35.748	570	6.40
MC05F	0.072	0.050	84.4	35.748	593	6.80
MC05F	0.073	0.022	84.4	35.748	528	6.50
MC05F	0.052	0.029	84.4	35.748	872	6.50
MC05S	0.071	0.043	86.2	39.742	638	6.80
MC05S	0.066	0.029	86.2	39.742	753	6.50
MC06F	0.066	0.043	84.5	42.511	530	6.80
MC06F	0.060	0.028	84.5	42.511	612	6.80
MC06S	0.038	0.028	80.7	32.844	452	6.40
MC06S	0.088	0.043	80.7	32.844	389	6.88
MC06S	0.061	0.036	80.7	32.844	434	6.90
MC06S	0.079	0.038	80.7	32.844	493	6.71
MC06S	0.038	0.036	80.7	32.844	347	6.90
MC06S	0.041	0.021	80.7	32.844	549	6.51
MC06S	0.057	0.036	80.7	32.844	645	6.50
MC06S	0.057	0.028	80.7	32.844	521	6.40
MC06S	0.056	0.028	80.7	32.844	486	6.45
MC06S	0.047	0.028	80.7	32.844	879	6.80
MC07X	0.089	0.117	84.5	79.433	573	6.47
MC07X	0.072	0.227	84.5	79.433	320	6.80
MC07X	0.079	0.176	84.5	79.433	503	6.40
MC07X	0.087	0.161	84.5	79.433	618	6.55
MC07X	0.062	0.220	84.5	79.433	525	6.42
MC07X	0.079	0.168	84.5	79.433	516	6.40
MC07X	0.065	0.176	84.5	79.433	616	6.50
MC08Y	0.053	0.049	.	.	521	6.31
MU010	0.075	0.526	42.7	87.036	888	6.32
MU020	0.051	0.433	43.3	43.416	901	6.40
MU030	0.042	0.368	47.2	50.518	710	6.32
MU040	0.055	0.389	41.8	80.380	746	6.32
PU02F	0.140	0.166	40.2	85.743	465	6.70
PU03S	0.083	0.108	35.6	99.003	521	6.80
RD010	0.200	1.216	58.6	78.190	551	6.38
RD020	0.120	2.228	43.5	134.912	594	6.32
RD030	0.139	0.838	64.5	83.782	681	6.40
RD040	0.125	1.801	67.3	83.608	751	6.35
ST010	0.180	1.641	31.8	117.058	481	6.40
ST020	0.154	1.051	34.4	105.889	417	6.28
ST030	0.181	1.751	35.7	77.330	417	6.47
ST040	0.123	1.262	34.0	89.125	424	6.20

Appendix C TANK TRIAL DATA

TANK TRIAL DATA AND STATISTICS - EASTERN ONTARIO SOURCES

seed*source*B water*depth*(mm)*280

plant number	tiller number	florets per panicle	mean fruit weight (mg/fruit)	FN	FSTDERR	panicle emergence date	panicle emergence date	trial year
101B1	0	44	28.07	35	0.812	81	1	82
101B2	0	36	.	.	.	80	0	82
101B3	0	73	23.88	29	0.835	88	8	82
102B1	0	.	18.84	16	1.026	82	2	82
102B1	1	.	.	.	.	91	11	82
102B2	0	50	28.86	11	1.080	81	1	82
102B2	1	28	.	.	.	113	33	82
102B3	0	67	26.39	36	0.529	86	6	82
103B1	0	57	.	.	.	88	8	82
103B2	0	90	28.19	22	1.107	91	11	82
103B2	1	.	24.34	5	1.962	102	22	82
103B3	0	.	18.60	32	0.802	93	13	82
104B1	0	47	26.48	6	3.347	82	2	82
104B1	1	45	24.81	34	0.645	91	11	82
104B1	2	32	26.32	11	1.229	98	18	82
104B2	0	55	23.17	22	0.436	87	7	82
109B1	1	.	22.35	11	1.037	.	.	82
501B1	0	48	30.08	25	0.824	82	2	82
501B1	1	52	30.79	31	0.873	86	6	82
501B1	2	50	33.72	36	1.076	86	6	82
501B1	3	.	25.97	6	0.937	99	19	82
501B2	0	.	.	.	.	138	58	82
501B9	9	23	.	.	.	.	.	82
502B1	0	35	30.42	4	1.442	82	2	82
502B1	1	32	24.15	15	0.929	87	7	82
502B1	2	28	25.55	16	1.057	90	10	82
502B2	0	41	30.00	1	.	82	2	82
502B2	1	33	28.57	6	6.057	88	8	82
502B2	2	42	21.30	11	1.057	91	11	82
502B3	0	47	17.89	12	0.415	92	12	82
503B1	0	55	30.22	10	0.833	88	8	82
503B1	1	50	26.79	16	0.993	91	11	82
503B1	2	40	26.00	24	0.759	99	19	82
503B2	0	19	34.00	8	1.240	92	12	82
504B1	0	60	30.00	1	.	82	2	82
504B1	1	44	21.58	22	0.539	91	11	82
504B2	0	71	26.96	7	1.641	.	.	82
504B2	1	50	22.67	19	0.584	96	16	82

seed*source*B water*depth*(mm)*430

plant number	tiller number	florets per panicle	mean fruit weight (mg/fruit)	FN	FSTDERR	panicle emergence date	panicle emergence date	trial year
209B1	0	32	25.15	24	0.542	92	12	82
209B2	0	33	28.34	8	0.770	103	23	82
209B2	1	31	21.21	9	1.300	115	35	82
210B1	0	22	29.06	10	0.893	95	15	82
210B2	0	15	17.78	10	1.474	96	16	82
210B2	1	18	15.40	2	1.700	120	40	82
210B3	0	19	27.50	2	0.300	109	29	82
210B3	1	21	.	.	.	.	.	82
211B1	0	15	31.80	7	1.881	88	8	82
211B2	0	27	25.88	9	2.278	91	11	82
211B2	1	39	24.06	7	1.229	108	28	82
211B2	2	33	.	.	.	118	38	82
212B1	0	18	27.33	13	0.768	92	12	82
212B2	0	30	29.79	26	1.872	92	12	82
609B1	0	25	.	.	.	82	2	82
609B1	1	32	23.56	17	0.808	99	19	82
609B2	0	18	25.56	9	1.178	95	15	82
610B1	0	44	40.17	9	2.010	86	6	82
610B2	0	28	42.99	9	2.434	87	7	82
611B1	0	14	32.89	7	2.597	80	0	82
611B1	1	18	23.45	11	0.853	89	9	82
611B1	2	18	24.25	2	1.350	97	17	82
611B2	0	25	.	.	.	102	22	82
611B2	1	25	.	.	.	106	26	82
611B2	2	32	.	.	.	130	50	82
612B1	0	31	.	.	.	86	6	82
612B1	1	19	30.30	9	1.280	100	20	82
612B2	0	10	.	.	.	111	31	82
612B2	1	10	.	.	.	140	80	82

seed*source*B water*depth*(mm)*590

plant number	tiller number	florets per panicle	mean fruit weight (mg/fruit)	FN	FSTDERR	panicle emergence date	panicle emergence date	trial year
317B1	0	24	26.10	12	1.671	88	8	82
317B1	1	21	33.75	17	1.811	102	22	82
317B1	2	32	27.66	27	0.975	103	23	82
318B1	0	15	37.42	6	2.906	86	6	82
318B1	1	23	40.33	14	1.786	101	21	82
318B1	2	23	39.10	2	4.800	111	31	82
318B2	0	43	26.26	18	0.673	99	19	82
318B9	9	21	.	.	.	.	.	82
319B1	0	12	27.95	2	1.250	82	2	82
319B1	1	.	20.98	6	0.791	92	12	82
319B2	0	21	38.34	7	2.825	91	11	82
319B2	1	22	32.42	16	1.475	108	28	82
319B2	2	23	29.18	18	1.151	110	30	82
319B9	9	17	.	.	.	.	.	82
320B1	0	31	29.21	18	1.273	86	6	82
320B1	1	36	30.26	31	0.594	101	21	82
320B1	2	34	29.86	17	0.990	103	23	82
718B1	0	25	35.63	9	1.758	96	16	82
718B1	1	31	27.12	8	1.480	110	30	82
718B1	2	21	34.15	6	1.276	110	30	82
718B2	0	7	26.25	8	1.304	137	57	82
719B1	0	36	22.47	4	1.571	85	5	82
719B1	1	36	23.06	20	0.800	99	19	82

seed*source*B water*depth*(mm)*590

plant number	tiller number	florets per panicle	mean fruit weight (mg/fruit)	FN	FSTDERR	panicle emergence date	panicle emergence date	trial year
719B1	2	43	19.94	40	0.557	102	22	82
719B2	0	36	22.37	24	0.567	101	21	82
720B1	0	18	.	.	.	112	32	82
720B1	1	20	44.50	13	1.149	121	41	82
720B1	2	21	45.40	10	1.428	129	49	82
720B1	3	21	36.12	13	2.575	131	51	82
720B1	4	25	42.85	17	3.101	132	52	82
720B1	5	24	.	.	.	141	61	82
720B1	6	19	.	.	.	.	.	82
720B9	8	14	.	.	.	.	.	82
720B9	9	14	.					

seed*source*B water*depth*(mm)*740

plant number	tiller number	florets per panicle	mean fruit weight (mg/fruit)	FN	FSTDERR	panicle emergence date	panicle emergence date	trial year
426B1	0	27	21.95	11	2.735	112	32	82
426B1	1	18	37.12	5	1.985	130	50	82
426B2	0	26	29.03	7	2.142	128	48	82
426B9	9	10	.	.	.	.	.	82
427B1	0	15	36.72	4	1.209	103	23	82
427B1	1	14	.	.	.	118	38	82
427B1	2	15	.	.	.	140	60	82
427B9	9	.	41.79	9	3.711	.	.	82
428B1	0	27	34.08	12	1.154	108	28	82
428B1	1	34	34.37	10	2.575	121	41	82
428B1	2	23	36.72	5	2.301	130	50	82
825B1	0	8	39.85	2	1.950	114	34	82
825B1	1	17	.	.	.	134	54	82
826B1	0	18	35.06	14	1.519	116	36	82
826B1	1	22	50.00	1	.	138	58	82
826B1	2	20	41.29	7	2.862	.	.	82
826B1	3	17	32.73	3	1.828	.	.	82
828B1	0	26	29.10	7	1.834	98	18	82
828B1	1	23	.	.	.	114	34	82
828B2	0	.	.	.	.	129	49	82

seed*source*C water*depth*(mm)*280

plant number	tiller number	florets per panicle	mean fruit weight (mg/fruit)	FN	FSTDERR	panicle emergence date	panicle emergence date	trial year
105C1	0	36	23.89	15	0.526	93	13	82
105C1	1	33	.	.	.	104	24	82
105C2	0	20	30.61	17	1.888	97	17	82
105C9	9	.	21.71	7	1.137	.	.	82
106C1	0	32	32.01	28	0.748	92	12	82
106C1	1	24	35.16	11	1.026	103	23	82
106C1	2	29	.	.	.	104	24	82
106C2	0	31	24.72	17	1.868	99	19	82
106C2	1	29	22.59	14	0.650	105	25	82
106C2	2	26	21.38	10	1.255	107	27	82
106C3	0	19	.	.	.	100	20	82
106C3	1	12	.	.	.	107	27	82
107C1	0	90	.	.	.	86	6	82
107C1	1	58	20.35	40	0.446	93	13	82
107C1	2	45	20.62	40	0.349	96	16	82
107C2	0	19	24.98	13	1.062	96	16	82
108C1	0	37	20.48	10	0.806	83	3	82
108C1	1	45	21.09	34	0.449	87	7	82
108C1	2	42	22.54	34	0.576	88	8	82
108C1	3	32	20.31	13	1.454	96	16	82
108C2	0	18	31.60	15	1.484	93	13	82
108C2	1	25	28.65	22	0.978	92	12	82
108C2	2	20	.	.	.	107	27	82
505C1	0	46	.	.	.	82	2	82
505C1	1	40	24.74	38	0.499	87	7	82
505C1	2	39	21.76	24	0.379	92	12	82
505C2	0	38	24.62	14	0.539	82	2	82
505C3	0	25	24.97	21	0.857	87	7	82
505C3	1	16	22.72	12	0.832	101	21	82
506C1	0	55	28.81	10	1.449	91	11	82
506C1	1	40	27.03	6	0.750	97	17	82
506C1	2	44	28.20	3	2.458	98	18	82
506C1	3	34	27.23	3	1.049	103	23	82
506C1	4	24	.	.	.	104	24	82
506C1	5	31	27.85	2	5.950	133	53	82
506C2	0	9	.	.	.	103	23	82
507C1	0	55	25.08	33	0.881	86	6	82
507C1	1	48	21.88	22	1.010	91	11	82
507C1	2	41	22.08	14	1.405	97	17	82
507C2	0	19	28.33	14	1.079	91	11	82
507C2	1	18	.	.	.	102	22	82
507C3	0	21	.	.	.	98	18	82
508C1	0	51	22.11	11	0.790	91	11	82
508C1	1	50	22.10	29	0.452	92	12	82
508C1	2	39	24.03	9	0.577	95	15	82
508C1	3	28	19.30	2	2.100	100	20	82
508C1	4	30	.	.	.	102	22	82
508C1	5	21	22.95	2	0.150	111	31	82
508C1	6	24	24.70	2	1.400	111	31	82

seed*source*C water*depth*(mm)*430

plant number	tiller number	florets per panicle	mean fruit weight (mg/fruit)	FN	FSTDERR	panicle emergence date	panicle emergence date	trial year
209C2	1	.	21.21	9	1.300	.	.	82
213C1	0	19	.	.	.	106	26	82
213C1	1	17	27.03	12	1.808	109	29	82
213C1	2	20	.	.	.	115	35	82
213C1	3	23	24.42	35	0.811	118	38	82
213C1	4	21	28.86	7	1.257	130	50	82
214C1	0	.	28.95	2	11.050	82	2	82

plant number	tiller number	florets per panicle	mean fruit weight (mg/fruit)	FN	FSTDERR	panicle emergence date	panicle emergence date	trial year
214C1	1	.	.	.	.	101	21	82
214C1	2	.	23.87	3	2.874	103	23	82
214C2	0	11	27.73	6	0.533	91	11	82
214C2	1	17	34.82	4	2.625	107	27	82
214C3	0	8	25.43	6	1.515	101	21	82
215C1	0	17	33.17	3	1.374	82	2	82
215C1	1	14	.	.	.	98	18	82
215C1	2	13	24.56	9	1.180	102	22	82
215C2	0	18	29.01	13	3.156	96	16	82
218C1	0	23	26.51	15	0.726	98	18	82
216C1	1	20	29.30	2	2.300	104	24	82
216C1	2	24	27.07	3	0.984	107	27	82
216C2	0	7	38.50	1	.	109	29	82
613C1	0	14	37.90	2	2.300	91	11	82
613C1	1	22	39.08	5	1.404	105	25	82
613C1	2	22	21.45	2	1.450	117	37	82
613C1	3	19	.	.	.	132	52	82
614C1	0	14	30.75	2	0.750	88	8	82
614C1	1	20	25.26	5	2.249	100	20	82
614C2	0	13	35.84	5	1.075	91	11	82
614C2	1	15	33.10	1	.	105	25	82
615C1	0	19	32.90	4	1.725	91	11	82
615C1	1	17	27.50	1	.	105	25	82
615C2	0	18	39.80	1	.	91	11	82
616C1	0	24	31.03	9	1.196	98	18	82
616C1	1	22	.	.	.	126	46	82
616C2	0	.	25.75	2	1.950	.	.	82
616C2	1	.	22.30	2	4.400	131	51	82

seed*source*C water*depth*(mm)*590

plant number	tiller number	florets per panicle	mean fruit weight (mg/fruit)	FN	FSTDERR	panicle emergence date	panicle emergence date	trial year
321C1	0	12	36.17	11	1.280	106	26	82
321C1	1	13	29.10	5	2.838	118	38	82
321C1	2	11	.	.	.	.	.	82
321C1	3	13	.	.	.	140	60	82
321C2	0	10	41.38	5	1.816	120	40	82
321C2	1	14	.	.	.	138	59	82
322C1	0	13	38.80	1	.	88	8	82
322C1	1	15	44.87	9	1.436	102	22	82
322C2	0	20	24.99	13	0.735	100	20	82
322C2	1	26	.	.	.	114	34	82
322C2	2	4	33.12	5	2.966	125	45	82
323C1	0	16	31.78	12	1.768	101	21	82
323C1	1	18	21.60	6	2.387	121	41	82
323C2	0	30	27.54	12	1.068	100	20	82
323C2	1	15	27.24	22	1.815	110	30	82
323C2	2	27	28.86	11	2.035	114	34	82
323C2	3	16	34.32	13	1.335	117	37	82
324C1	0	23	26.32	17	0.540	96	16	82
324C1	1	22	30.88	14	0.917	106	26	82
324C1	2	24	37.68	18	1.314	107	27	82
324C1	3	13	24.88	5	2.021	122	42	82
721C1	0	10	32.00	6	1.343	104	24	82
721C1	1	14	31.78	9	2.619	120	40	82
721C2	0	12	.	.	.	107	27	82
721C2	1	13	34.10	3	3.691	121	41	82
721C2	2	13	35.47	3	2.876	123	43	82
721C9	9	9	.	.	.	.	.	82
722C1	0	18	37.02	6	5.557	92	12	82
722C1	1	13	43.62	6	1.846	104	24	82
722C1	2	17	37.30	1	.	107	27	82
722C2	0	16	25.00	8	1.948	98	18	82
722C2	1	13	28.00	1	.	114	34	82
722C2	2	13	19.26	5	3.010	120	40	82
723C1	0	15	.	.	.	91	11	82
723C1	1	18	34.94	14	1.091	100	20	82
723C2	0	11	39.30	5	1.047	101	21	82
723C2	1	15	22.90	1	.	127	47	82
723C3	0	8	23.30	1	.	112	32	82
723C3	1	11	31.85	2	1.850	.	.	82
724C1	0	18	34.93	8	1.872	88	18	82
724C1	1	22	.	.	.	111	31	82
724C1	2	29	30.49	10	1.702	112	32	82

seed*source*C water*depth*(mm)*740

plant number	tiller number	florets per panicle	mean fruit weight (mg/fruit)	FN	FSTDERR	panicle emergence date	panicle emergence date	trial year
430C1	0	12	36.96	7	1.394	115	35	82
430C1	1	15	.	.	.	136	56	82
430C1	2	13	.	.	.	139	59	82
431C1	0	11	48.40	1	.	104	24	82
431C1	1	.	.	.	.	127	47	82
431C2	0	11	34.30	5	2.265	114	34	82
432C1	0	22	35.91	8	1.474	94	14	82
432C1	1	19	34.86	9	1.450	103	23	82
432C1	2	17	35.45	4	1.289	103	23	82
432C1	3	27	36.30	1	.	108	28	82
432C2	0	.	.	.	.	108	28	82
830C1	0	18	37.75	4	1.891	108	28	82
830C1	1	25	44.86	14	1.054	.	.	82
830C1	2	18	.	.	.	137	57	82
830C2	0	.	41.70	9	2.084	.	.	82
831C1	0	9	.	.	.	109	29	82
831C1	1	9	52.97	3	1.870	122	42	82
831C2	0	10	.	.	.	121	41	82
831C2	1	10	52.10	2	3.700	.	.	82
832C1	0	14	33.87	11	0.503	104	24	82
832C1	1	18	29.30	6	1.468	120	40	82
832C1	9	.	29.30	6	1.468	.	.	82
832C2	0	18	44.80	5	0.871	107	27	82
832C2	1	16	36.30	2	1.000	127	47	82

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seed*source*I water*depth*(mm)*280

mean fruit weight (mg/fruit)	FN	FSTDERR
28.03	100	0.874

mean seed weight	SN	SSTDERR
23.28	95	0.504

tiller number	florets per panicle	panicle emergence date
168	42	26
173	25	26
174	38	26
204	17	26
205	14	26
206	30	26
207	33	26
208	21	26
209	17	15
210	29	26
221	27	26
260	15	33
261	23	33
263	23	33
288	.	33
309	27	33
310	23	33
328	34	33
363	22	40
364	16	40
365	23	40
371	27	40
408	25	40
410	26	40
452	17	70
453	26	70
454	36	70
483	28	70
484	20	70
485	27	70
486	15	70
488	19	70
697	20	70
698	30	70
699	21	70
700	22	70
701	24	70
702	16	70
703	21	70
704	23	70
705	20	70
706	20	70

seed*source*I water*depth*(mm)*430

mean fruit weight (mg/fruit)	FN	FSTDERR
27.82	100	0.588

mean seed weight	SN	SSTDERR
21.97	99	0.446

tiller number	florets per panicle	panicle emergence date
84	20	18
91	55	22
92	19	22
116	26	22
137	44	22
139	30	22
181	26	26
184	43	26
191	19	26
224	20	26
235	42	26
275	20	33
281	30	33
331	21	33
332	27	33
339	31	33
344	30	33
380	23	40
382	53	40
383	29	40
385	31	40
386	21	40
419	40	40
421	49	40
422	33	40
504	23	70
505	18	70
506	30	70
507	18	70
508	66	70
511	22	70
512	24	70
513	36	70
514	17	70
515	20	70
516	23	70
517	18	70
518	20	70
519	22	70
520	15	70
521	22	70
562	22	70
563	23	70
564	30	70
718	39	70
719	41	70
720	37	70
721	24	70
722	38	70
723	31	70
724	30	70
726	33	70
727	28	70
728	25	70
729	21	70
730	28	70
731	19	70
732	16	70
733	16	70
734	30	70

seed*source*I water*depth*(mm)*590

mean fruit weight (mg/fruit)	FN	FSTDERR
25.63	82	0.549

mean seed weight	SN	SSTDERR
20.73	81	0.450

tiller number	florets per panicle	panicle emergence date
89	19	18
128	19	22
148	25	22
200	28	26
240	33	26
295	23	33
296	19	33
297	28	33
349	28	33
398	16	40
431	21	40
435	25	40
436	25	40
536	21	70
537	21	70
538	25	70
539	28	70
540	31	70
541	21	70
542	15	70
543	21	70
544	21	70
545	17	70
586	19	70
587	18	70
588	16	70
589	21	70
590	21	70
591	14	70
592	26	70
593	28	70
594	20	70
595	33	70
596	21	70
597	27	70
761	15	70
762	21	70
763	20	70
764	28	70
765	25	70
766	30	70
767	25	70
768	20	70
769	30	70
770	20	70
771	24	70

seed*source*I water*depth*(mm)*740

mean fruit weight (mg/fruit)	FN	FSTDERR
30.78	98	0.503

mean seed weight	SN	SSTDERR
25.17	77	0.422

tiller number	florets per panicle	panicle emergence date
41	25	15
75	25	18
134	27	22
248	37	26
252	34	26
303	24	33
304	21	33
305	73	33
357	26	33
401	17	40
440	22	40
447	25	40
613	29	70
614	21	70
615	21	70
616	15	70
617	15	70
618	23	70
619	14	70
620	17	70
621	16	70
629	25	70
630	44	70
631	29	70
632	38	70
633	28	70
634	43	70
635	32	70
636	16	70
637	26	70
787	46	70
788	39	70
802	34	70
803	43	70
804	23	70
805	19	70
806	16	70
807	17	70
808	21	70
809	22	70
810	24	70

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seed*source*P water*depth*(mm)*280

mean fruit weight (mg/fruit)	FN	FSTDERR
28.47	100	0.817

mean seed weight	SN	SSTDERR
23.41	89	0.787

tiller number	florets per panicle	panicle emergence date
5	18	9
8	.	9
8	23	10
13	20	10
17	11	15
18	.	15
20	29	15
28	15	15
44	22	15
47	9	18
48	23	18
52	25	18
53	18	18
62	26	18
80	16	22
81	18	22
82	14	22
85	21	22
88	.	22
97	24	22
100	20	22
104	16	22
109	24	22
110	22	22
111	27	22
153	17	26
158	10	26
159	22	26
160	17	26
164	14	26
165	19	26
171	16	26
172	16	26
254	9	33
255	20	33
256	14	33
257	17	33
262	17	33
264	15	33
265	19	33
270	26	33
271	12	33
272	18	33
273	18	33
311	23	33
319	20	33
320	17	33
329	23	33
389	12	40
396	20	40
485	15	70
486	23	70
493	8	70
494	21	70
695	13	70
696	18	70

seed*source*P water*depth*(mm)*430

mean fruit weight (mg/fruit)	FN	FSTDERR
30.73	108	0.851

mean seed weight	SN	SSTDERR
27.54	102	0.911

tiller number	florets per panicle	panicle emergence date
3	18	9
4	.	9
22	.	15
30	20	15
32	19	15
32	12	15
33	15	15
45	18	15
55	15	18
65	14	18
67	14	18
90	26	22
115	17	22
117	12	22
123	20	22
127	21	22
138	19	22
141	20	22
146	31	22
178	14	26
179	26	26
180	12	26
182	15	26
183	12	26
192	17	26
193	16	26
228	17	26
230	13	26
231	14	26
236	22	26
279	18	33
282	30	33
283	27	33
338	15	33
384	16	40
387	28	40
425	15	40
426	13	40
495	15	70
498	19	70
497	27	70
498	22	70
498	15	70
500	25	70
509	15	70
510	13	70
725	22	70
741	21	70

seed*source*P water*depth*(mm)*590

mean fruit weight (mg/fruit)	FN	FSTDERR
35.51	80	0.772

mean seed weight	SN	SSTDERR
31.35	80	0.860

tiller number	florets per panicle	panicle emergence date
1	8	1
2	7	3
9	25	10
10	14	10
36	13	15
37	15	15
39	21	15
68	18	18
93	20	22
94	42	22
96	14	22
131	15	22
132	16	22
194	36	26
238	24	26
239	23	26
289	42	33
293	23	33
294	26	33
351	17	33
390	21	40
522	24	70
523	11	70
553	40	70
554	15	70
555	24	70
556	19	70
557	23	70
558	29	70
559	32	70
598	26	70
599	29	70
600	33	70
601	17	70
772	10	70

seed*source*P water*depth*(mm)*740

mean fruit weight (mg/fruit)	FN	FSTDERR
38.37	79	1.180

mean seed weight	SN	SSTDERR
33.95	72	1.033

tiller number	florets per panicle	panicle emergence date
7	14	9
12	13	10
24	12	15
40	.	15
57	12	18
72	27	18
74	16	18
133	20	22
201	14	26
245	.	26
247	19	26
251	22	26
299	16	33
300	13	33
301	15	33
302	18	33
306	.	33
307	.	33
354	14	33
355	20	33
439	17	40
441	19	40
442	12	40
443	25	40
649	14	70
650	20	70
651	23	70
652	13	70
653	17	70
654	17	70
655	24	70
677	14	70
678	8	70
679	13	70
680	18	70
785	11	70
786	18	70
814	28	70

TANK TRIAL DATA AND STATISTICS - EASTERN ONTARIO SOURCES

seed*source=R water*depth=(mm)=280

mean fruit weight (mg/fruit)	23.48	FN	FSTDERR
		104	0.852
mean seed weight	18.85	SN	SSTDERR
		100	0.494

tiller number	florets per panicle	panicle emergence date
16	35	15
27	43	15
28	42	15
46	29	18
59	26	18
61	31	18
83	38	18
77	49	22
86	24	22
98	34	22
105	27	22
150	22	26
151	32	26
152	.	26
156	15	26
157	32	26
166	32	26
177	.	26
211	37	26
212	22	26
215	24	26
216	26	26
217	26	26
218	28	26
219	22	26
269	18	33
312	33	33
313	33	33
317	34	33
318	18	33
323	29	33
366	23	40
368	32	40
412	27	40
414	26	40
415	31	40
467	25	70
468	25	70
469	16	70
470	23	70
471	24	70
472	18	70
473	28	70
474	32	70
475	32	70
476	30	70
477	30	70
478	20	70
479	23	70
480	20	70
482	28	70
487	27	70
489	32	70
490	27	70
491	30	70
492	36	70
690	24	70
691	25	70
692	25	70
693	17	70
694	17	70
707	24	70
708	24	70
709	21	70
710	21	70
711	14	70

seed*source=R water*depth=(mm)=430

mean fruit weight (mg/fruit)	26.82	FN	FSTDERR
		108	0.837
mean seed weight	22.84	SN	SSTDERR
		100	0.782

tiller number	florets per panicle	panicle emergence date
23	44	15
66	44	18
120	28	22
121	35	22
124	34	22
140	33	22
145	28	22
188	27	26
189	.	26
227	38	26
229	38	26
377	38	40
381	26	40
423	.	40
424	25	40
567	32	70
568	32	70
569	35	70
570	20	70
571	15	70
572	14	70
573	18	70
574	20	70
575	40	70
576	57	70
577	27	70
578	21	70
579	35	70
580	16	70
581	19	70
582	44	70
583	26	70
584	16	70
585	12	70
714	39	70
715	26	70
716	29	70
717	38	70
742	31	70
743	36	70
744	20	70
745	28	70
746	21	70
747	35	70
748	32	70
749	36	70

seed*source=R water*depth=(mm)=590

mean fruit weight (mg/fruit)	23.54	FN	FSTDERR
		105	0.544
mean seed weight	19.63	SN	SSTDERR
		100	0.429

tiller number	florets per panicle	panicle emergence date
129	39	22
199	30	26
237	64	26
346	46	33
347	35	33
348	22	33
350	67	33
393	24	40
394	33	40
428	45	40
429	61	40
430	26	40
524	44	70
525	18	70
526	38	70
527	48	70
528	47	70
529	31	70
530	38	70
531	36	70
532	39	70
533	18	70
534	17	70
535	31	70
602	28	70
603	24	70
604	26	70
605	29	70
606	50	70
607	36	70
608	18	70
609	37	70
610	24	70
611	32	70
612	27	70
755	42	70
756	15	70
757	41	70
773	25	70
774	22	70
775	29	70
776	20	70
777	32	70
778	21	70
779	31	70
780	29	70

seed*source=R water*depth=(mm)=740

mean fruit weight (mg/fruit)	25.49	FN	FSTDERR
		100	0.562
mean seed weight	21.36	SN	SSTDERR
		98	0.378

tiller number	florets per panicle	panicle emergence date
78	27	18
244	41	26
407	39	40
408	34	40
437	40	40
438	45	40
448	31	40
449	.	40
638	23	70
639	24	70
640	28	70
641	39	70
642	25	70
643	27	70
644	38	70
645	29	70
646	41	70
647	20	70
648	23	70
656	36	70
657	36	70
658	33	70
659	33	70
660	48	70
661	43	70
662	38	70
663	31	70
664	31	70
665	42	70
666	23	70
667	47	70
668	34	70
669	37	70
790	44	70
791	45	70
792	40	70
793	35	70
794	48	70
795	38	70
796	34	70
797	44	70
798	36	70
799	23	70
800	41	70
801	31	70

TANK TRIAL DATA AND STATISTICS - EASTERN ONTARIO SOURCES

seed*source=S water*depth*(mm)=280

mean fruit weight (mg/fruit)	19.74	FN	FSTDERR
		31	0.838
mean seed weight	18.43	SN	SSTDERR
		27	0.775

tiller number	florets per panicle	panicle emergence date
14	20	10
25	29	15
50	40	18
51	27	18
58	20	18
83	34	22
84	28	22
87	33	22
99	19	22
101	31	22
103	24	22
107	17	22
161	24	28
162	34	28
163	15	28
169	.	28
170	30	26
175	28	26
176	32	26
213	32	28
214	19	28
222	19	28
223	33	28
250	20	28
258	51	33
259	28	33
286	23	33
287	30	33
308	25	33
314	22	33
315	22	33
316	21	33
321	18	33
322	23	33
324	22	33
325	15	33
326	23	33
327	31	33
330	33	18
373	30	40
374	29	40
375	12	40
413	33	40
416	21	40
417	27	40
418	24	40
455	23	70
456	26	70
457	20	70
458	25	70
459	20	70
460	17	70
461	16	70
462	26	70
463	19	70
464	21	70
681	31	70
682	19	70
683	17	70
684	32	70
685	21	70
686	27	70
687	23	70
688	25	70
689	19	70
712	20	70
713	25	70

seed*source=S water*depth*(mm)=430

mean fruit weight (mg/fruit)	19.54	FN	FSTDERR
		100	0.680
mean seed weight	18.12	SN	SSTDERR
		96	0.633

tiller number	florets per panicle	panicle emergence date
21	30	15
31	27	15
34	.	15
35	38	15
54	41	18
88	25	22
118	31	22
119	32	22
122	26	22
125	20	22
126	28	22
142	22	22
143	26	22
144	31	22
147	49	22
185	27	26
186	23	26
187	23	26
190	.	26
225	31	26
226	34	26
232	30	26
233	35	26
234	34	26
274	13	33
276	15	33
277	40	26
278	24	33
280	29	33
284	38	33
333	30	33
334	.	33
335	15	33
337	33	33
338	23	33
340	34	33
341	39	33
342	45	33
343	35	33
345	33	40
378	31	40
379	18	40
388	29	40
389	32	70
420	31	70
501	29	70
502	25	70
503	21	70
565	28	70
566	9	70
735	29	70
736	33	70
737	31	70
738	30	70
739	28	70
740	26	70
750	37	70
751	33	70
752	35	70
753	35	70
754	29	70

seed*source=S water*depth*(mm)=590

mean fruit weight (mg/fruit)	26.42	FN	FSTDERR
		102	0.794
mean seed weight	23.72	SN	SSTDERR
		100	0.606

tiller number	florets per panicle	panicle emergence date
11	18	10
38	8	15
56	42	18
70	19	18
71	10	18
95	21	22
130	31	22
195	44	26
196	41	26
197	29	26
198	18	26
241	11	26
242	25	26
243	32	26
285	20	33
286	17	33
287	42	33
288	27	33
290	26	33
291	26	33
292	40	33
352	9	33
353	28	33
391	38	40
392	31	40
395	26	40
396	22	40
397	28	40
398	15	40
433	13	40
434	10	40
546	22	70
547	18	70
548	36	70
549	34	70
550	12	70
551	19	70
552	20	70
560	27	70
561	23	70
758	20	70
759	17	70
760	21	70

seed*source=S water*depth*(mm)=740

mean fruit weight (mg/fruit)	23.24	FN	FSTDERR
		33	1.213
mean seed weight	19.29	SN	SSTDERR
		30	1.212

tiller number	florets per panicle	panicle emergence date
42	18	15
43	13	15
73	34	18
135	20	22
136	26	22
149	31	22
202	17	26
203	21	26
248	27	26
249	.	26
253	21	26
298	21	33
356	13	33
358	28	33
359	21	33
360	10	33
361	30	33
362	19	33
400	15	40
402	17	40
403	15	40
404	17	40
405	29	40
444	22	40
445	25	40
446	23	40
450	26	40
622	29	70
623	18	70
624	16	70
625	28	70
626	40	70
627	32	70
628	13	70
670	20	70
671	26	70
672	26	70
673	27	70
674	28	70
675	19	70
676	24	70
781	31	70
782	12	70
783	32	70
784	30	70
789	29	70
811	21	70
812	16	70
813	27	70

Appendix D

LABORATORY METHODS - DETAILED NOTES

D.1 PHOSPHATE

Extractant for 40 samples (ref. McKeague, pp 174)

Bray Extractant

2.216g ammonium fluoride
+4.2 ml hydrochloric acid conc.
per 2000ml

OR

30ml 1.0M ammonium fluoride
25ml 1.0M hydrochloric acid
per 1000ml

Reagents for 250 samples (ref. page 101)

A. Acid Molybdate-Antimony
7.5g ammonium molybdate
0.14g antimony potassium tartarate
88.0ml sulfuric acid (s.g.=1.84)
per 1000ml

B. Ascorbic Acid (reducing agent) MIX DAILY
0.25g ascorbic acid
per 10ml

C. Molybdate Reagent Blank (found to be not necessary)
400ml reagent 'A'
100ml deionized water
per 500ml

D. Molybdate Reagent (working reagent, MIX DAILY)
40ml reagent 'A'
10ml reagent 'B'
per 50ml

Standard

1M potassium dihydrogen phosphate (monobasic)
136.09g KH_2PO_4 per 1 of (extractant diluted to 5/7 with deionized water)
Useful Range - 0.01 to 0.3 mM

Procedure

Extracting - 20ml sediment sample into 50ml extractant
- shake 1 hour at 45rpm.
- filter under vacuum - wash through and make up to volume (100ml)

Analysis (1/11 method - sample concentration is x11)
(analyse duplicate or triplicate samples)
5ml deionized water
+ 0.5ml extractant
+ 1ml reagent 'D'
mix by inversion
let stand 1 hour (stable, possibly for days)
measure O.D. at 885nm

D.2 AMMONIUM

Extractant

2M potassium chloride (149.12g KCL per 1)

Reagents (for 500 samples)

Alkaline Stock
160g sodium citrate
8g sodium hydroxide
per 800ml

Hypochlorite Stock
commercial javel bleach - 200ml

Nitroprusside Reagent - MIX DAILY
± 0.15g sodium nitroprusside
per 30ml

Phenol Reagent (CAUTION in handling - use fume hood; avoid skin contact)
25g phenol crystals
per 250ml ethyl alcohol

Oxidizing Reagent - MIX DAILY
4 parts alkaline stock
1 part hypochlorite stock

Dilute Reagent for 60 samples
(this is a modification of other methods-found to be stable and reduce errors due to mixing - suitable for the concentrations encountered)

24ml Phenol Reagent
600ml deionized water
24ml Nitroprusside Reagent
dilution of extractant is 1/20

Standard

0.01 to 1.0mM ammonium chloride in 5/7 dilution of extractant
(1M = 53.49g NH_4Cl per 1)

Procedure

Extracting - 20ml sediment sample into 50ml extractant
shake 1 hour at 45 rpm
filter under vacuum
rinse and mak up to volume

Diluting - dilute 5/105

Analysis (1/21 method)
10ml dilute reagent
+ 0.5ml sample
agitate by inversion - CRITICAL
+ 1.0ml oxidizing reagent
agitate by inversion - CRITICAL
let stand 1 hour (more or less stable 1-24 hours)
measure O.D. at 640nM
sample is x21

NOTE: agitation is critical - for this reason run samples in triplicate and run again if agreement is poor

D.3 CALCIUM AND MAGNESIUM
by atomic absorption spectroscopy

Extractant
1.0M ammonium acetate

Reagent
Lanthanum Chloride Buffer
58.65g Lanthanum Oxide
100ml deionized water
250ml hydrochloric acid conc. (add carefully)
per 1000ml
Dilute Buffer
1 part Lanthanum buffer
4 parts water

Standard
Calcium - 1ml=1mg Ca
2.497g calcium carbonate
±100ml 1M hydrochloric acid (CAUTION - add slowly until dissolved)
per 1000ml

Magnesium - 1ml=1mg Mg
3.469 g magnesium carbonate
±100ml 1M hydrochloric acid (CAUTION - add slowly until dissolved)
per 1000ml

Standard Stock (2.5 ppm CA; 0.5ppm Mg) - use to calibrate batch
2.5ml Ca standard
0.5ml Mg standard
per 1000ml

Standard Series
.417ml 100ppm standard + 10ml dilute La Buffer =4ppm
.204ml 100ppm standard + 10ml dilute La buffer =2ppm

Procedure Water
use 1/11 for Ca (10ml dilute La buffer + 0.417ml sample)
use 1/50 for Mg (15ml dilute La buffer + 0.303ml sample)

Procedure Sediment

Extracting
20ml sediment sample
50 extractant
shake 1 hour at 45rpm
filter under vacuum
rinse and make up to volume

Analysis
dilute 1/200 (15ml dilute La buffer +0.0754ml extractant)
analyse on atomic absorption spectrometer

D.4 POTASSIUM

Extractant

1.0M ammonium acetate

Reagent

none required

Dilution

1/11 - 10ml deionized water + 1ml extract
3/13 - 10ml deionized water + 3ml extract

Standard

0.3mM potassium chloride -
0.5ml +10ml HOH = 1/21 (0.014mM)
1.0ml +10ml HOH = 1/11 (0.027mM)
1.5ml +10ml HOH = 1/7.666 (0.039mM)
2.0ml +10ml HOH = 1/6 (0.050mM)

Procedure

Extraction
50ml extractant
+20ml sediment sample
shake 1 hour at 45rpm
filter under vacuum thru Whatman No. 1 paper filter
rinse and make up to volume

Analysis
dilute 1/11 and 3/13
analyse on atomic absorption spectrometer

D.5 IRON, ZINC, COPPER, MANGANESE

Extractant

0.1m hydrochloric acid (8.3ml conc HCl per 1000ml)

Reagents

none required

Standards refer to McKeague, 1978 and Stainton et al., 1975

Iron - A - 3.59 x 10-3M (200ppm) - dilute 20ml/100ml water = 40ppm

B - 40ppm - dilute 1ml + 10ml HOH = 65.27uM

- dilute 0.5ml + 10ml HOH = 34.19uM

Manganese -:

Copper -:

Zinc -:

Procedure

Extraction

50ml extractant

20ml sediment sample

shake 1 hour at 45 rpm

vacuum filter thru Whatman No. 1 paper filter

rinse and make to volume Dilution

1/11 - 10ml deionized water + 1.00ml extract

11/100 - 10ml deionized water + 0.1515ml extract