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INVESTIGATION INTO THE DISAPPEARANCE OF EURASIAN WATER MILFOIL IN THE KAWARTHA LAKES

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Management Perspective

Eurasian watermilfoil (*Myriophyllum spicatum* L.) invaded the Kawartha Lakes area of Ontario in the late 1960's. Rapid disappearances of milfoil were observed in Chemung Lake and Rondeau Bay in 1977. No explanation for the disappearances was apparent. Similar disappearances of milfoil were observed in the 70's in Lake Wingra, Wisconsin and in the 60's in Chesapeake Bay, Maryland. Studies of the disappearance phenomena in the U.S., conducted after the fact, examined pesticides, pathogens, diseases, sediment nutrition, sediment density, water chemistry, climate, toxin accumulation, epiphytic and macrophytic competition. The conclusion was that no one factor could be identified as responsible.

Since 1979, we have observed a slow decline of milfoil from Buckhorn Lake; and since 1980, we have attempted to determine if the sediments are responsible. In 1986, a rapid disppearance of milfoil from Scugog Lake was observed and insect grazing was a possible factor. We expanded our program, therefore, to include sediments from approximately 50 locations in 4 lakes and surveyed 75 sites in 15 lakes for insect grazing damage.

Sediments were ruled out as a factor in the disappearance of milfoil. Insect grazing damage was extensive in the Kawartha and Rideau Lakes and strong circumstantial evidence would suggest that insect grazing was responsible for the disappearance.

Perspective - Gestion

Le myriophylle blanchissant (*Myriophyllum spicatum* L.) a envahi la région des lacs Kawartha en Ontario à la fin des années 1980. Une disparition rapide du myriophylle a été observée dans le lac Chemung et la baie Rondeau en 1977. Aucune explication de cette disparition n'a pu être donnée. Des disparitions semblables du myriophylle ont été observées dans les années 1970 dans le lac Wingra, au Wisconsin, et dans les années 1960 dans la baie de Chesapeake, au Maryland. Les études de ce phénomène de disparition aux Etats-Unis, effectuées après le fait, en ont cherché la cause dans les pesticides, l'émission de pathogènes, les maladies, la nutrition des sédiments, la densité des sédiments, les caractéristiques chimiques de l'eau, le climat, l'accumulation de toxines, la compétition épiphytique et macrophytique. Aucune n'a pu identifier un seul facteur qui pourrait être responsable du phénomène.

Depuis 1979, nous avons observé une lente disparition du myriophylle dans le lac Buckhorn; depuis 1980, nous avons tenté de déterminer si les sédiments étaient responsables du phénomène. En 1986, une disparition rapide du myriophylle a été observée dans le lac Scugog et les insectes sont apparus comme une des causes possibles du phénomène. Nous avons élargi notre programme en conséquence pour inclure les sédiments d'environ 50 endroits dans 4 lacs différents et avons étudié 75 sites de 15 lacs pour évaluer les dommages causés par le broutage par les insectes.

Les sédiments ont été éliminés comme facteur de disparition du myriophylle. Le broutage par les insectes est intense dans les lacs Kawartha et Rideau et un grand nombre de données circonstantielles laisse croire que les insectes seraient responsables de la disparition du myriophylle.

Résumé (le 5 mars 1987)

Le myriophylle blanchissant, une plante aquatique nuisible, a rapidement disparu de trois des lacs Kawartha sans aucune raison apparente. Le rôle des sédiments dans la croissance et la disparition du myriophylle a été étudié dans les lacs Buckhorn, Chemung et Scugog, trois des lacs Kawartha, et les lacs Opinicon et Rideau. Selon Carignan (1984), l'eau interstitielle prélevée en certains endroits du lac Buckhorn d'où le myriophylle avait disparu était caractérisée par de fortes concentrations d'ammoniaque et de sulfure d'hydrogène et de faibles concentrations de fer et de phosphore, ainsi que par un faible potentiel d'oxydo-réduction. Les tests de croissance effectués par Carignan (1984) ont éliminé la carence en fer et la toxicité par le sulfure d'hydrogène; la toxicité de l'ammoniac a également été éliminée au cours de tests de croissance similaires effectués dans le cadre de la présente étude. Aucune corrélation entre l'abondance du myriophylle et les caractéristiques chimiques de l'eau interstitielle, le potentiel d'oxydo-réduction des sédiments, la géochimie des sédiments et la chimie tissulaire du myriophylle n'a été observé dans 49 sites. Dans les tests de croissance, une réduction de 6.8 % de la densité des sédiments a réduit la croissance de 42 %; par contre, l'addition de matières organiques sous forme de sciure a permis de réduire la croissance de 81 %, même sans diminuer de la densité des sédiments. Certaines substances phénoliques, courantes dans la litière du myriophylle, étaient toxiques, mais les concentrations nécessaires pour provoquer une réponse étaient élevées. La croissance du myriophylle sur les sédiments provenant de régions d'où le myriophylle avait récemment disparu a été comparée à la croissance sur des sédiments provenant de régions où il est encore abondant. Aucune différence significative n'a pu être établie entre les sites "bon" et "mauvais" et vitesse de croissance; cela laisse penser que ce ne sont pas les sédiments qui sont à l'origine de la disparition rapide du myriophylle dans les lacs Kawartha. Des données circonstantielles laissent croire que les insectes seraient responsables de cette disparition.

Abstract (March 5, 1987)

Eurasian watermilfoil, a nuisance aquatic plant, rapidly disappeared from three Kawartha Lakes for no apparent reason. The role of sediment in the growth and disappearance of milfoil was examined in Buckhorn, Chemung, and Scugog, three Kawartha Lakes, and Opinicon, a Rideau Lake. Carignan (1984) claimed that sediment pore water from sites in Buckhorn Lake, where milfoil had disappeared, were characterized by high ammonia and hydrogen sulphide concentrations and low iron, and phosphorus concentrations and low redox potential. Growth experiments conducted by Carignan (1984) ruled out iron limitation and hydrogen sulphide toxicity. In this study, ammonia toxicity was also ruled out in similar growth experiments. No correlation between milfoil abundance and sediment pore water chemistry, sediment redox potential, sediment geochemistry and milfoil tissue chemistry was observed from 49 sites. In growth experiments, a 6.8% reduction in sediment density reduced growth by 42%; but the addition of organic matter in the form of sawdust inhibited growth 81% even though sediment density was not reduced. Some phenolic substances, common in milfoil litter, were toxic but the concentrations required to illicit a response were high. Milfoil growth on sediments from areas where milfoil had recently disappeared was compared to growth on sediments where milfoil was still abundant. No significant difference was evident between "good" and "bad" sites, nor did the addition of

growth rates; thus suggesting that the sediments were not responsible for the rapid decline of milfoil from the Kawartha Lakes. Circumstantial evidence suggests that insect grazing was responsible for the disappearance.

Introduction (March 5, 1987)

Eurasian watermilfoil (Myriophyllum spicatum L.) is a nuisance aquatic macrophyte which can adversely impact recreational activities; clog water intakes; depress real estate values; decrease dissolved oxygen levels; interfere with commercial fishing; and increase mosquito populations in infested lakes, reservoirs, and rivers (Bates et al., 1986). A typical invasion of milfoil is characterized by a pattern of explosive growth followed by declining abundance (Carpenter, 1980). This type of growth is commonly exhibited when introduced species invade an area and have left behind their natural competitors enabling them to compete with and often dominate existing native species. M. spicatum was introduced to North America from Eurasia in the late 1800's according to Reed (1977) but Couch and Nelson (1985) recently disputed this early introduction and claimed that the earliest record for Myriophyllum spicatum was 1942. Although milfoil usually grows rapidly immediately after its dispersal to a new lake, some milfoil infestations have been known to lag behind dispersal (Bayley et al., 1968). Evidence suggests, however, that once an invasion of milfoil has occurred, it usually persists for only 5-10 years before its abundance is decimated (Carpenter, 1980).

The unexpected decline of milfoil has stimulated several researchers to examine possible factors responsible for the reduced abundance. In Lake Wingra, Wisconsin, milfoil dramatically declined in 1977 after being the dominant macrophyte since 1969 (Carpenter, 1980). Carpenter (1980) assessed the following plausible hypotheses to explain the decline: toxin accumulation, herbicides and harvesting, climate, nutrients, epiphytes, competition from other macrophytes, and parasites or pathogens. He concluded that no one factor alone could account for the decline of biomass and that a multifactor synergistic mechanism was involved. Jones et al. (1983) examined the possible role of phytoplankton as a factor in the decline of milfoil in Lake Wingra; however, the causal mechanisms remain in doubt since it is not known whether the phytoplankton increase preceded or followed the decline.

In Chesapeake Bay, Maryland, milfoil populations also declined dramatically (Bayley et al., 1968). Bayley and her coworkers believed that pathological diseases, namely Northeast disease and Lake Venice disease were responsible for the 95% decline in the milfoil population between 1965 and 1967. In a later investigation, Bayley et al.(1978) attributed the disappearance of milfoil to several interrelated environmental factors including tropical storms, turbidity, salinity, and disease. Increased turbidity and turbulence, resulting from unusual weather during the early growing season, was thought to be responsible for the reduction of biomass in the Currituck Sound, North Carolina in 1978. Stevenson and Confer (1978), however, suggest that the general decline of milfoil abundance in Chesapeake Bay cannot be attributed solely to turbidity; since in some subestuaries where milfoil has disappeared, turbidity has actually decreased.

Barko (1983) found that reduced milfoil biomass occurred in areas with high sediment organic content, and that additions of organic matter to the sediment could potentially inhibit milfoil growth. It has been recognized that as lakes age, the sediment organic matter increases and submersed aquatic plants eventually decline (Wetzel, 1979; Carpenter,1981). Barko and Smart (1986) suggested in their most recent paper that the influence of sediment density is greater than the influence of sediment organic content in regulating macrophyte growth. They speculated that sediment density regulates nutrient uptake by influencing nutrient diffusion distances, and consequently, influences growth. They concluded that growth appears to be governed by the availability of nutrients in sandy and organic sediments. Nutrient limitation of milfoil growth was tested in situ by Anderson and Kalff (1985) in an experiment involving nitrogen, phosphorus, and potassium enrichment. The growth response to fertilization in Lake Memphremagog revealed that milfoil was limited by sediment nitrogen. No response to additions of phosphorus and potassium were observed. Average increases in milfoil biomass were 30-40 % upon addition of ammonia, but only 7-17 % of the variance in the milfoil biomass indicators could be explained by measurements of exchangable nitrogen. Anderson and Kalff (1986), in another report, attempted to relate species distribution and abundance in Lake Memphremagog to sediment nutrient chemistry and concluded that milfoil presence or absence was not related to sediment nutrient chemistry; milfoil abundance was not significantly related to exchangable nitrogen;

and only 14 % of the variance in milfoil abundance could be explained by exchangeable phosphorus, the only significant relationship observed for milfoil. Both Barko's work and Anderson and Kalff's work suggest that a nutrient-limited condition in the sediment will determine the possible standing crop of milfoil. Additions of organic material over time in the form of milfoil litter will encourage a nutrient-limited condition in the sediment, and therefore, a gradual reduction in milfoil standing crop. The disappearances of milfoil from several lakes, however, have been observed to involve the complete disappearance of milfoil over a very short period of time.

Since it is not yet clear what role the sediment plays in the disappearance of milfoil, we chose to examine the hypothesis that either an inhibiting or a toxic substance, or the development of a nutrient limitation in the sediment may be responsible for the decline of milfoil from several Kawartha Lakes in Ontario. This report summarizes work that has been conducted over the last six years in Buckhorn, Chemung, and Scugog Lakes; all of which have experienced severe infestations of milfoil and subsequent disappearances.

Methods (March 5, 1987)

Lake surveys for milfoil areal distribution and abundance were conducted each fall during the peak in standing crop. The entire lake was surveyed by boat and the areal extent of the milfoil weed beds was marked on the navigational maps. The extent of the lake's surface occupied by milfoil was ranked into four cover-abundance categories (Heavy, >75% cover; Moderate, 25-75%; Light, 1-25%; and None, <1%). One site in Buckhorn was sampled monthly from 1979 to 1984 during the growing season, and once in 1986, for milfoil seasonal standing crop estimates using plant density and plant weight measurements to calculate areal standing crop as described by Painter (1986).

The toxicity of pore water ammonia to milfoil growth was examined in a growth experiment similar to Carignan (1984). The yield of milfoil biomass over an 8 week period on sediments amended with ammonia was compared to the same sediment unamended. Twelve replicates of each ammonia concentrations were performed and three milfoil tips, 15-20 cm long , were planted in each replicate. The ammonia concentrations tested were chosen to exceed the pore water ammonia concentrations observed in Buckhorn Lake. The maximum level of ammonia in Buckhorn Lake pore waters reported by Carignan (1984) was 2600 uM; the concentrations in the amended sediment were approximately 2100, 2500, 3460, and 5450 uM; the control unamended sediment had 1700 uM.

The effect of varying sediment density and organic content was examined in growth experiments performed in a greenhouse over a four to five week period. Growth rates were measured as stem length increases over weekly intervals. Vermiculite (20 g) was added to three replicate pots containing 2 liters of "good" sediment to decrease sediment density; and 3, 10 cm milfoil apical tips were planted per replicate. "Good" sediment was defined as sediment which currently supported nuisance biomass levels of milfoil at the site. Two other treatments involved the addition of sawdust on the "good" sediment surface (2cm), and the addition and homogenization of 20 g (wet) of sawdust to the "good" sediment to study the effect of organic matter amendments. A final experiment involved the addition of 20 g (dry) of activated charcoal to decrease the dissolved organic carbon concentration in the pore water of a "bad" sediment. "Bad" sediment was defined as a sediment which had supported milfoil growth in the past but currently supported little or no biomass. "Good" and "bad" sediment controls were performed.

The potential of different sediments to support healthy milfoil growth rates was examined using "good" sediments versus "bad" sediments. All sediments were tested unamended and amended with a complete nutrient solution (Long Ashton Solution, Hewitt, 1966) to determine if the sediment nutrients were limiting. Sediments were obtained from Buckhorn, Chemung, and Scugog Lakes from a total of 21 locations using an Eckman grab sampler. Three replicate, 2 liter pots were planted with five, 10 cm apical milfoil tips. The growth experiments were performed in a greenhouse over a 37 day period. Stem length was measured at the beginning, middle, and end of the experiment and growth rates were calculated as the average stem length increase per day. The experimental design had approximately 30% error associated with the calculated growth rates.

Phenolic bioassays were performed using ellagic acid, vanillic acid, vanillin, cinnamic acid, cinnamaldehyde, protocatechuic acid, protocatechualdehyde, syringic acid, syringaldehyde, gentisic acid, and gentisaldehyde. The initial bioassays were performed in an incubator with fluorescent lighting using phenolic concentrations of 125 and 25 mg/l. A second set of bioassays were conducted using those phenolic compounds which killed milfoil at the 25 mg/l concentration; but were performed in natural sunlight for 12 days using phenolic concentrations of 2.5 and 0.25 mg/l. Each bioassay was performed in an 8 l Belco jar with nutrient media (Long Ashton). Five apical milfoil tips were used for each trial and were considered dead when no green colour was visible in the leaves and apical tip.

Nutrient status of sediment pore water, sediment cores, and milfoil tissue was assessed for 41 sites in Buckhorn, Chemung, and Opinicon Lakes which supported varying densities of milfoil. Pore water samples were obtained using an _in situ_ sampler consisting of dialysis tubing inserted inside perforated 12" ABS pipe sections. The sampler was pushed down into the sediment close to the milfoil root mass and left to equilibrate for 48 hours. Pore water was analyzed for PO_4, NO_3, Ca, K, Na, Mg, DIC, pH, Mn and S. Sediments were sampled using a plexiglass corer with rubber stoppers fitted into the ends. Samples were extruded immediately after the sampling, so that depth profiles of redox and in situ pH could be determined. Redox measurements were made at 0, 5, 10, 15, and 20 cm depths. Eh readings were corrected for the calomel reference (+244 mV). Samples were homogenized, sieved to pass through a 1mm mesh screen, dried, ground, and later analyzed for ionic content. Sediment samples were analyzed for P, N, Ca, K, Na, Mg, and Mn. Sediment density and loss on ignition (LOI) were determined by drying and igniting a known volume of sediment at 550 C for two hours. Sediment phosphorus fractions were analyzed according to the method described in Mayer and Williams (1981). Biologically-available phosphorus was determined using the 0.1 N NaOH extraction procedure described by Williams et al. (1980). Total phosphorus was determined on a 1 N HCl extract of an ashed sample.

Plant material for tissue analysis was dried, ground in a Wiley mill, and extracted with 6N HCl for analysis. Plant material was analyzed for Na, K, Mg, P, Ca, and Mn.

Cations were analyzed on the Jarrell-Ash Atomic Absorption Spectrophotometer. Phosphate and nitrogen was analyzed by colorimetric and semi-micro Kjeldahl methods respectively.

Fifteen lakes in the Kawartha and Rideau Waterways were surveyed for insect grazing damage and the abundance of two known herbivores of milfoil, the aquatic caterpillar of Acentria nivea and the aquatic larva of the weevil, Litodactylus *leucogaster*. Five sites per lake were sampled and five, 25 cm apical tips of milfoil were collected per site and preserved in Kahle's Solution. Insect grazing damage was qualitatively estimated using the following rating scheme: 0- no damage; 1- one of either necrotic spots, leaves eaten, or stem bore holes; 2- two of the previous symptoms; 3- three of the symptoms; 4- the apical tip missing; 5- apical tip missing plus one of the symptoms; 6- apical tip missing plus two of the symptoms; and 7- apical tip missing plus three of the symptoms. Aquatic caterpillar and weevil larvae were counted. At five locations in Buckhorn Lake, a further twenty-two, 25 cm apical tips were examined at each site to estimate the aquatic caterpillar abundance.

The impact of varying aquatic caterpillar densities on milfoil growth was determined using ten, 10 cm milfoil tips incubated in Long Ashton Solution in a incubator. Four, eight, thirteen, and eighteen larvae were added to the 8 litre Belco Jars containing the milfoil. Milfoil fresh weight was determined every four days for sixteen days.

Results and Discussion (March 5, 1987)

The areal cover of aquatic vegetation for 1972, in Buckhorn (Figure 5) and Chemung (Figure 1), two Kawartha Lakes, was described by Wile (1976). An unexplained disappearance of milfoil occurred in Chemung Lake in 1977 (Wile et al., 1979) and as of 1986, the milfoil has not returned (Figure 2). Seasonal total macrophyte biomass, seasonal milfoil biomass in lower Chemung Lake, and the contribution of milfoil to the annual biomass from 1971 to 1978 is illustrated in Wile et al. (1979); and presented in Figure 3. From 1971 to 1976, milfoil contribution to the total annual submerged macrophyte biomass increased from 6.4% to 50.4%, and in 1977/78 drastically declined to approximately 4% of the total vegetation. In 1978, the seasonal standing crop of total vegetation and the species compostion was similar to preceding years. Wile et al. (1979) discussed possible factors for the disappearance of milfoil such as limited tissue phosphorus and nitrogen concentrations. Tissue chemistry remained relatively constant and non-limiting from 1971 to 1977 (Table 1) and therefore could not explain the disappearance. Wile et al. (1979) observed leaf deformities and mentioned the possibility of a pathogen which was also described in Bayley et al. (1968). The fused-leaved symptoms have also been observed by Nagy et al. (1986) and were reportedly caused by sub-lethal exposures to 2,4-D. Since the local cottage owners were using 2,4-D for shoreline control of milfoil, the observed deformities may have been caused by drift of the herbicide out of the treated area.

Carpenter and Adams (1977) determined the mineral content of M. spicatum to examine the possibility that nutrient limitation may explain the disappearance of milfoil in Lake Wingra. Based on Gerloff's critical phosphorus concentration of 0.07% for maximum growth, Carpenter and Adams (1977) concluded that although phosphorus was the most probable limiting mineral, macrophyte growth was not limited by nutrients in Lake Wingra. Schmitt and Adams (1981), however, showed that reduced photosynthetic rates of M. spicatum occurred at tissue phosphorus levels below 0.3% and pointed out that the data first thought to dispute the phosphorus deficiency hypothesis now indicates that phosphorus may, in fact, be limiting. Even though there is a discrepancy in the literature concerning the critical concentration of phosphorus required for optimal photosynthesis and yield, the data of seasonal tissue phosphorus concentrations from 1971 (Adams and McCraken, 1974), 1975, and 1977 (Carpenter, 1980) reveals that tissue phosphorus seasonal trends were similar in the three years which represents a time span from the beginning of the milfoil infestation in Lake Wingra to the year the milfoil declined (Figure 4). Thus, phosphorus does not appear to be solely responsible for the disappearance of milfoil in Lake Wingra.

Milfoil was the dominant aquatic plant in Buckhorn Lake in 1972 (Wile,1976) and therefore the map of total aquatic vegetation (Figure 5) can be assumed to represent milfoil distribution in Buckhorn. Areal cover of milfoil in Buckhorn Lake observed between 1972 and 1986 is illustrated in Figures 5-12 and summarized in Table 2. Between 1972 and 1986 the areal cover of milfoil declined from 78% to 1% with significant changes in 1979 and 1986. Milfoil biomass at one site in Buckhorn Lake (BB1) was monitored regularly between 1979 and 1984. Even though fluctuations of biomass did occur at this site from year to year, no gradual decline was evident; but by 1986, the milfoil had virtually disappeared (Figure 13). Tissue phosphorus concentrations of milfoil collected from the site did not decline during the period prior to the disappearance (Figure 14) which was also observed from Chemung Lake and Lake Wingra as described above. Surficial sediment was analyzed for phosphorus fractions from 1979 to 1986 and no depletion of sediment phosphorus was evident (Table 3). Although climatic changes might explain some of the yearly variability, such widespread and rapid disappearances of the milfoil beds must be related to some other factor. The areas where milfoil has disappeared are now vegetated by native plant species. Wile et al. (1979) also observed the return of native aquatic plants in Chemung Lake in 1977 and 1978 suggesting that the sediment and water quality conditions can support plant growth.

During the course of our sediment experiments, a disappearance of milfoil was also observed from many areas in Lake Scugog in 1986. Three locations monitored from early May to early July were estimated to have 75-100% milfoil cover, but by mid-July the plants appeared unhealthy. Estimates of milfoil cover abundance revealed that two of the three previously dense milfoil stands were completely decimated by early September and the other site dropped to 25-50% cover abundance (Appendix 1). These observed declines contradict past seasonal trends because early September is usually the time of year when milfoil biomass peaks (Adams and McCracken, 1974).

Similarily, a rapid collapse in milfoil was reported by Carignan (1984) in Buckhorn Lake. He observed a dramatic decrease in an apparently healthy milfoil population at one station between early and mid-June with no recovery the next year. In an effort to identify the cause of the observed spacial and temporal variability, Carignan (1984) characterized the sediment geochemistry of several sites in Buckhorn Lake that sustained variable milfoil biomasses. He found that sediments sustaining low or declining biomasses were characterized by relatively high NH_4^+, K, DIC, and H_2S concentrations. Although most stations which sustained low macrophyte biomasses had very low pore water PO_4^{3-} and Fe, some stations which sustained similar biomasses had relatively high PO_4^{3-} and Fe concentrations. This contradiction led Carignan (1984) to suggest that some other chemical factors may be responsible for the apparent toxicity of some sediments to macrophytes.

One factor Carignan (1984) investigated was redox potential which he found to be linearly related to milfoil biomass (Figure 15). Carignan suggested that over time, decomposition of dense macrophyte stands elevates the labile organic matter influx to the sediment, which results in the accumulation of reducing end products, and subsequently lowers the redox potential. To further substantiate Carignan's observed relationship between redox potential and milfoil biomass, we sampled and determined the redox potential at thirty-four stations in Buckhorn, Chemung, and Opinicon Lakes with varying milfoil biomasses. Redox potential was measured at 0, 5, 10, 15, and 20 cm depths within the sediment and the average redox potential was calculated. The sediments with low, medium, and high milfoil densities had average redox potentials of +151, +103, and +141 respectively and the standard deviations indicate no significant differences (Appendix 2).

Carignan (1984) also examined the possibility that Fe was limiting by performing a growth experiment using three sediments, two of which supported little or no milfoil biomass in the field. He found that Fe additions only slightly stimulated milfoil growth (Figure 16) and that the differences in growth observed between "good" and "bad" sites could not be explained by Fe limitation alone.

Although poor growth of hydrophytes has been associated with H_2S build-up (Howes et al., 1981), Carignan (1984) ruled out H_2S toxicity as a factor explaining poor milfoil growth based on growth experiments he conducted using sediment from a site which sustained high milfoil biomass (Figure 17).

Based on Carignan's (1984) findings that elevated NH_4^+ levels were present in sediments sustaining little or no milfoil biomass, we conducted NH_4^+ toxicity bioassays to determine if NH_4^+ concentrations could be reached which would prove detrimental to the growth of milfoil. All plants demonstrated healthy growth (2 cm/day) over the course of the experiment, even at the highest concentration of NH_4^+ (5450 uM) which was approximately 13 times greater than the natural NH_4^+ concentrations observed in Buckhorn Lake (400uM). When comparing shoot (fresh weight, dry weight and length) and root (fresh weight, dry weight) biomass measurements to the NH_4^+ concentrations, we concluded that a 4 to 13 fold increase in NH_4^+ concentration above natural levels in Buckhorn Lake did not influence the growth of milfoil ($p<0.05$, Figure 18).

In an attempt to determine if the decline of milfoil biomass in Buckhorn, Chemung and Opinicon Lakes was a function of limiting sediment nutrients, we examined 41 sites with varying milfoil abundances. At the same time, Carignan (1984) was also investigating the sediment geochemistry at 8 sites in Buckhorn Lake. The pore water chemistry from both studies was pooled together and split into three categories based on milfoil cover abundance (Appendix 2). Concentrations of PO_4, NO_3, Ca, K, Na, Mg, DIC, S, Mn, H_2S, CH_4, NH_4, Fe, Cl, and pH in sediment pore water were compared among sites with varying milfoil cover abundances (Figure 19). Concentrations of P, N, Na, Mg, Ca, K and Mn obtained from sediment cores were also compared among sites with varying milfoil cover abundances (Figure 20). It appears that milfoil abundance is not related to sediment pore water chemistry or sediment chemistry since the nutrient concentrations of cover abundance groupings range considerably and overlap. Pore water ammonia is the only exception to this trend. High levels of ammonia were found in areas of low milfoil abundance, but ammonia was measured at only 8 stations; and we experimentally determined that elevated ammonia concentrations did not effect milfoil growth. The low ammonia concentrations in high milfoil biomass locations are likely due to root uptake of ammonia from the pore water.

Shoots and roots of milfoil were analyzed for tissue nutrients (P, Mg, Mn, Na, K, and Ca) since they can be used as an index of nutrient availability for plant growth (Gerloff and Krombholz, 1966). Ranges in concentration of these nutrients did not vary greatly and the standard deviations between sites of differing milfoil biomass overlapped (Figure 20). In a recent report, Barko and Smart (1986) also found a poor relationship between nutrients in macrophyte shoots and macrophyte growth. They did find, however, that growth was highly correlated with nutrient accumulation which takes both tissue mass and nutrient concentrations into account to give a better representation of the plant's responsiveness to sediment conditions.

Sediment and pore water geochemistry and plant chemistry do not appear to readily explain the differing milfoil abundances in Buckhorn, Chemung and Opinicon Lakes. To explain the disappearing milfoil in Buckhorn Lake, Carignan (1984) hypothesized that intense decomposition of organic matter can lead to the accumulation of reducing end products in the sediment and that one or several of these end products may be toxic to root metabolism. Barko and Smart (1983) reported that sediments receiving a 5% addition of refractory organic matter remained inhibitory to the growth of Hydrilla verticillata for at least 14 weeks. To test the hypothesis that accumulation of organic matter in the sediment may inhibit milfoil, we chose to investigate the effect of various sediment additions on milfoil growth. To "bad" sediment, activated charcoal was added to remove dissolved organic carbon in the sediment. To "good" sediment, vermiculite was added to test the effect of decreasing sediment density on milfoil growth while not affecting the absolute nutrient content to which each plant was exposed. "Good" sediment was also amended with sawdust to determine if the addition of organic material could inhibit milfoil growth. Trials of sawdust mixed into the sediment and trials of sawdust layered on the surface of the sediment were performed. A comparison of average milfoil growth rates relative to the control sediments ("good" and "bad" sediment with no additions) revealed that both the addition of vermiculite to sediment and the layering of sawdust on the surface of the sediment reduced milfoil growth 42% ($p=0.015$), while the sediment amended with sawdust mixed in inhibited growth 81% ($p=0.001$, Appendix 3). The growth rates of plants growing in "bad" sediment amended with activated charcoal were not significantly different from the control, even though the dissolved organic carbon (DOC) concentrations of the control (1.4 mg/l) were slightly higher than activated charcoal amended sediment (0.5 mg/l). Barko and Smart (1983) found that growth inhibition was correlated to increasing concentrations of DOC in the interstitial water. Hydrilla verticillata, which has been shown to be ecologically and physiologically similar to M. spicatum (Barko and Smart, 1981) was inhibited by about 90% on sediment with DOC concentrations ≥400 mg/l (Barko and Smart, 1983). These concentrations are extremely high compared to the levels we found and explains why milfoil growth rates did not improve with the addition of activated charcoal. We also can conclude that high DOC concentrations were not responsible for the observed poor growth of milfoil from the "bad" sediment site.

In another investigation, Barko and Smart (1986) speculated that sediment density regulated the nutrient uptake and consequently macrophyte growth by influencing nutrient diffusion distances. Indeed, the addition of vermiculite decreased sediment density 6.8% and presumably increased diffusion distances perhaps explaining the observed reduction of growth (Appendix 3). The 81% inhibition of growth on sediment amended with sawdust can not be explained using this rationale. The addition of sawdust increased the sediment organic content 4.5%, but instead of decreasing sediment density, the sawdust increased sediment density 2%. Therefore, the inhibition of growth by the addition of sawdust must be due to some other factor other than sediment density.

While the mechanism of inhibition is not known, Armstrong (1975, 1978) suggests that production of phytotoxins (metals, gases and dissolved sulphides) may be responsible. Some soluble organic carbon compounds produced from anaerobic decomposition of lignin and cellulose are known to be toxic to plants (Guenzi and McCalla, 1966). If there is inadequate oxygen transportation from the shoots to the roots, the plant will not be able to detoxify the rhizosphere (Armstrong, 1978).

Organic matter in the soil is primarily composed of humic substances (Schnitzer, 1971) and its subsequent oxidation yields phenolic compounds (Vallentyne, 1957). The influence of soil phenolic acids as plant growth inhibitors has been recognized for some time in terrestrial, particularily agricultural environments (Wang et al., 1977). Evidence suggests that these organic compounds may also play a role in aquatic systems by affecting growth of phytoplankton (Planas et al., 1981; Wium-Anderson et al., 1982) and macrophyte distribution and growth (Dooris et al.,1982; McNaughton, 1968; Wolek, 1974; Barltrop et al., 1984).

Szczepanski (1977) discussed the possibility of using allelopathic substances as a means of biological control of aquatic weeds. These substances can be released from leaves, stems, straw, bark, flowers, seeds, fruit, roots, and litter; and may inhibit any one of a plant's processes including photosynthesis, respiration, cell division, growth, uptake of ions, permeability of membranes, or enzyme production (Szczepanski, 1977).

Barko and Smart (1983) suggested that accumulation of toxic, soluble, organic compounds may in fact inhibit plant growth and subsequently contribute to the decline of submerged macrophyte species. It has been demonstrated that a naturally occurring growth inhibitor does exist which can effectively limit growth of Hydrilla verticillata under laboratory conditions (Dooris and Martin, 1980). Isolation and subsequent bioassays of the _Hydrilla_ growth inhibitor revealed the existence of a photodynamic effect that appears to be a singlet oxygen producer capable of inhibiting photosynthesis and enhancing respiration rates (Barltrop and Martin, 1983; Barltrop et al., 1984).

Planas et al. (1981) identified 18 phenolic compounds found in _M. spicatum_ tissue. The most common phenolics were ellagic, gallic, tannic, protocatechuic, 5-methoxyferulic, shikimic, caffeic, cinnamic, coumaric, ferulic, gentisic, pyrogallol, quinic, sinapic, and syringic acid. They also found that a mean of 7% of the plant's organic content was composed of these phenolic acids with a maximum phenolic content of 30% which can be considered extremely high compared to other plants. Although most researchers do not quantitatively report phenolic substance data, Kuwatsuka and Shindo (1973) reported rice straw to have a total ether-extractable phenolic content of 0.34%. The possibility of autoinhibition of milfoil by accumulation of phenolic acids derived from milfoil's own leaf litter prompted us to study the effect of exposing milfoil to various phenolic compounds with the hope of discovering one that may explain milfoil's eventual decline.

Gentisaldehyde and cinnamic acid killed milfoil within 72 hours at concentrations of 125 and 25 mg/l but had no effect at 2.5 and 0.25 mg/l. Cinnamaldehyde, vanillic acid, and syringaldehyde were also able to kill milfoil at 25 mg/l or greater but required 5-12 days. Vanillin, protocatechuic acid, protocatechualdehyde, and syringic acid did not kill milfoil at 25 mg/l but did at 125 mg/l. Neither gentisic acid nor ellagic acid affected milfoil at 125 mg/l. Literature suggests that natural levels of phenolic compounds in the sediment exist in concentrations far less than the concentrations required experimentally to ellicit a response (Hedges and Parker, 1976; Buikema et al., 1979). The task of isolating and finding the ideal concentration of one or more phenolic compounds that may be responsible for inhibiting milfoil growth would be extremely exhausting and in all probability unsuccessful. It is also quite possible that a combination of phenolic compounds would be necessary to result in milfoil inhibition in the field. Environmental factors such as photolytic action, microbial degradation, pH, water hardness, and temperature must also be considered since they affect toxicity of the phenol (Buikema et al., 1979).

In summary, the hypothesis that sediment may be responsible for the disappearance of milfoil has been dealt with extensively. Carignan (1984) found sediment redox potential was correlated to milfoil abundance in Buckhorn Lake, however, no evidence of this relationship was observed in our study of 34 sites in Buckhorn, Chemung and Opinicon Lakes. Based on sediment geochemistry and growth experiments, toxicity of NH_4^+ and H_2S and limitation of Fe were ruled out as factors that could explain the differences in standing crop. We pooled Carignan's (1984) data with the data we collected from Lakes Buckhorn, Opinicon, and Chemung and concluded from the pore water, sediment, and tissue chemistry results of 49 stations that no one nutrient was responsible for the observed milfoil abundances in these lakes. Barko and Smart (1986) examined 40 different sediment types across North America and concluded that sediment density, which is affected by the sediment organic content, influences the yield of milfoil by altering nutrient diffusion distances. We found that adding vermiculite to "good" sediment supported this hypothesis. The pronounced decrease in growth rates of milfoil grown on sediment amended with sawdust suggests that something other than a nutrient limitation was having an impact on the plants since sediment density was not decreased. At this point, we investigated the effect of various phenolic compounds on milfoil growth but realized that it was highly unlikely that we would ever isolate and find the ideal concentration of one or more phenolic compounds that could effectively inhibit milfoil growth in the field.

Since researchers have been unable to isolate a specific factor responsible for the observed disappearances of milfoil across North America, we felt it was necessary to examine sediment from lakes where milfoil had experienced a sudden decline to see if we could find any differences in the sediment's ability to support milfoil growth. Sediment was collected from both "good" and "bad" sites of Lakes Scugog, Buckhorn, and Chemung. Milfoil growth experiments were conducted on sediments from "bad" sites (locations that recently supported dense milfoil stands but no longer sustain milfoil growth) and compared to milfoil growth rates observed on sediments collected from "good" sites (locations which still support dense milfoil stands).

Healthy yet variable growth rates were observed for all sediments tested (Appendix 1, Figure 21). Growth rates did not differ between "good" and "bad" sediments suggesting that sediment chemistry was not responsible for the observed milfoil disappearance in the field. Nutrient additions to the same sediments did not improve the growth rates (Appendix 1, Figure 22) which also suggests that a nutrient limitation can not explain the disappearance of milfoil. Neither sediment density nor organic matter content were statistically different when "good" sediment was compared to "bad" sediment. In conclusion, sediment does not appear to be responsible for the decline of milfoil in the Kawartha Lakes.

Evidence for Biological Control

During a site inspection of Scugog Lake in the fall of 1985, severe grazing damage was observed on the milfoil plants. Most plants were missing the apical tip and many of the stems were bare. Closer examination of the plants revealed the presence of insect larvae, which were tentatively identified as the aquatic larva of the moth, Acentria nivea. Specimen identification was verified by US Army Engineer, Waterways Experiment Station, Environmental Laboratory (Vicksburg Miss.). Upon initiation of the growth experiments during the spring of 1986, we encountered great difficulty obtaining milfoil plants from the field and maintaining them in the greenhouse due to the feeding damage of the larvae. When we returned to the same locations two weeks later to collect more milfoil plants, we discovered that the milfoil had disappeared. In our search for insect-free milfoil plants to perform our growth experiment, milfoil material was obtained from lakes near Sudbury, Guelph, Port Stanley, Peterborough and Lakefield. Moth larvae and shelters were found on the plants collected from these areas. The decision was made to investigate the possibility that the moth larvae were responsible for the rapid disappearance of the milfoil we were observing at our field sites.

Just as Eurasian watermilfoil is an introduced plant specie from Eurasia, Acentria nivea is a native moth of Europe and was first observed on the North American continent in Montreal in 1927 (Sheppard, 1945). Judd (1950) subsequently reported the moth in the St. Lawrence River and in the vicinity of Lakes

Ontario and Erie. Lekic and Mihajlovic (1970) studied insect grazers of milfoil in Yugoslavia and recommended that Acentria be considered as a possible biological control agent for milfoil. In a study of insects and other macroinvertebrates associated with Eurasian watermilfoil in the United States, Balciunas (1982) concluded that aquatic moth larvae fed on milfoil voraciously and caused the most severe damage of any insect group. The moth's life cycle appears to be adequately suited to control milfoil. Milfoil, typically, has two standing crop peaks during the growing season, one in June and the other in September (Adams and McCracken, 1974) which coincides with periods of active feeding by the moth larva. Batra (1977) has described the life cycle of the moth but the key points are that there is only one generation per year and that the larval stage lasts 10.5 months. Buckingham et al. (1981) examined the possibility of biological control of milfoil using Acentria. They found that the larvae fed on other aquatic plants as well as milfoil, and the populations may be limited by natural enemies. They also found that Acentria already occurs in the northeastern U.S. in many areas where milfoil is problematic. Balciunas (1982) stated that although an individual Acentria larva can cause considerable damage, it remains to be determined whether populations occurring in the field are high enough to measurably reduce milfoil levels. Balciunas concluded that the use of Acentria as a biological control agent may be limited.

Fifteen lakes were surveyed in August 1986 to determine the geographical extent of insect grazing damage on milfoil

(Appendix 4). Figures 23 and 24 illustrate the median insect grazing damage estimate for the 25 apical tips sampled per lake. Ten of the fifteen lakes surveyed had severe grazing damage based upon our ranking scheme. Lakes with a median ranking of 4 had missing apical tips and a ranking of 5 meant that the 25 plants examined had missing apical tips plus one other damage symptom. When comparing the numbers of the aquatic moth larvae (Acentria) to the weevil larvae (Litodactylus), the moth larva occurred in greater numbers in 13 of the lakes. Initial survey of Buckhorn Lake observed 72 of 135 (53%) apical tips with larvae feeding at the apical tip and making cases by breaking off the tips, bending them back and cementing the tip to the remaining stem. In the ten lakes where the moth larvae were predominant and caused significant grazing damage, 122 moth larvae and 364 larval shelters were observed on 206, 25 cm apical tips (6 larvae and 17.7 larval shelters per 10 tips). Batra (1977) observed approximately 46% of 154 apical tips to have larval shelters. We observed approximately 4 times as many larval shelters as Batra observed. Our feeding trial experiments indicated that milfoil growth could cope with 4 larvae per 10 tips but larval abundances greater than 8 larvae per 10 tips had a severe impact (Figure 25). In the five lakes that did not experience significant insect grazing damage, only 6 larvae and 11 larval cases were observed on 79, 25 cm apical tips (0.76 larvae and 1.4 larval shelters per 10 tips).

Given the rapid disappearance of the milfoil from several locations in Scugog and Buckhorn Lakes during 1986, the insect grazing damage estimates for those lakes, and the high population of *Acentria* larvae relative to previously published population estimates, we conclude that insect grazing by the moth caterpillar was responsible for the disappearance of milfoil from Scugog and Buckhorn Lakes in 1986.

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Figure 21: Growth rate of milfoil in "good", "intermediate", and "bad" sediments collected from Lakes Buckhorn, Chemung, and Scugog.

Figure 22: Growth rates of milfoil in "good", "intermediate", and "bad" sediments collected from Lakes Buckhorn, Chemung, and Scugog. Solid bars represent growth rates in the sediments but amended with nutrients.

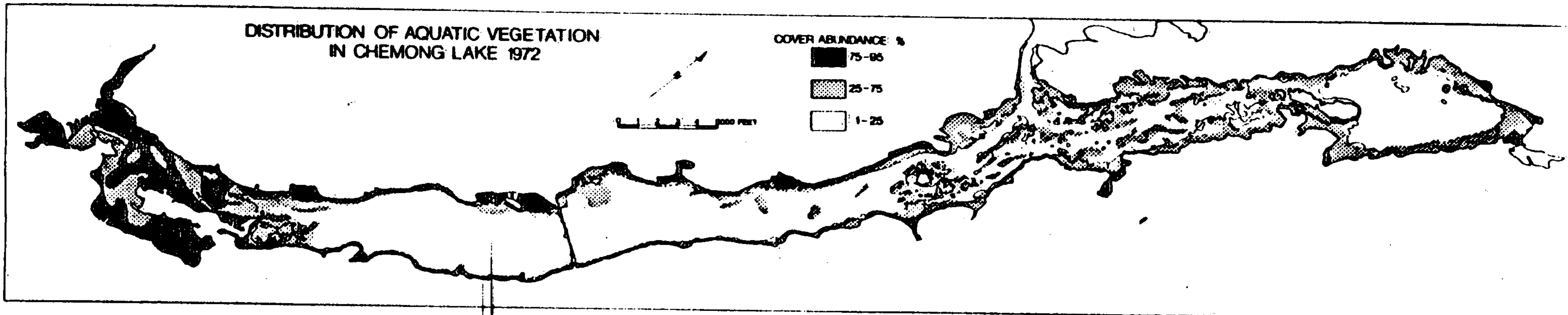
Figure 23-24: Insect grazing damage estimates for several Rideau and Kawartha Lakes and the proportion of weevil larvae versus moth larvae and cases observed.

Figure 25: Fresh weight of milfoil over time grazed upon by varying moth larvae densities.

Figure 1: Distribution and abundance of Aquatic Vegetation in Chemung Lake, 1972.

Figure 2: Distribution and abundance of milfoil in Chemung Lake, 1986.

DISTRIBUTION OF AQUATIC VEGETATION
IN CHEMONG LAKE 1972



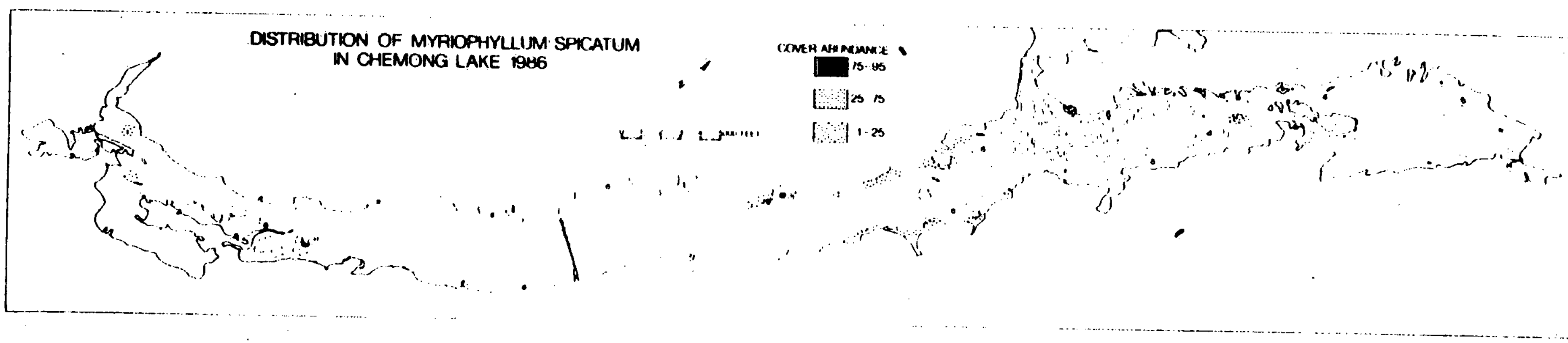

DISTRIBUTION OF MYRIOPHYLLUM SPICATUM
IN CHEMONG LAKE 1986
COVER ABUNDANCE
75-95
25-75
1-25

Figure 3: Seasonal macrophyte biomass (g dry wt./m^2) in lower Chemung Lake from May to October, 1971-1978. Shaded area represents seasonal milfoil biomass and the numbers represent the percent contribution of milfoil.

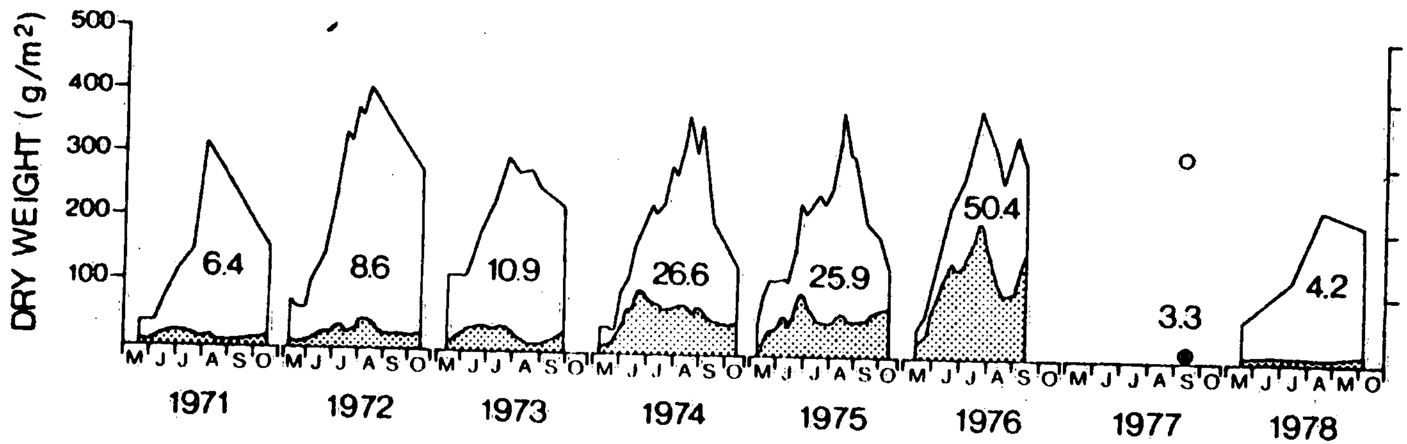

DRY WEIGHT (g/m²)
500
400
300
200
100
6.4
8.6
10.9
26.6
25.9
50.4
3.3
4.2
M J J A S O M J J A S O M J J A S O M J J A S O M J J A S O M J J A S O M J J A S O M J J A M O
1971
1972
1973
1974
1975
1976
1977
1978

Figure 4: Seasonal concentrations of phosphorus (% P/g DW) in milfoil shoots in Lake Wingra during 1971 (Adams and McCracken, 1974) and 1975/77 (Carpenter, 1980).

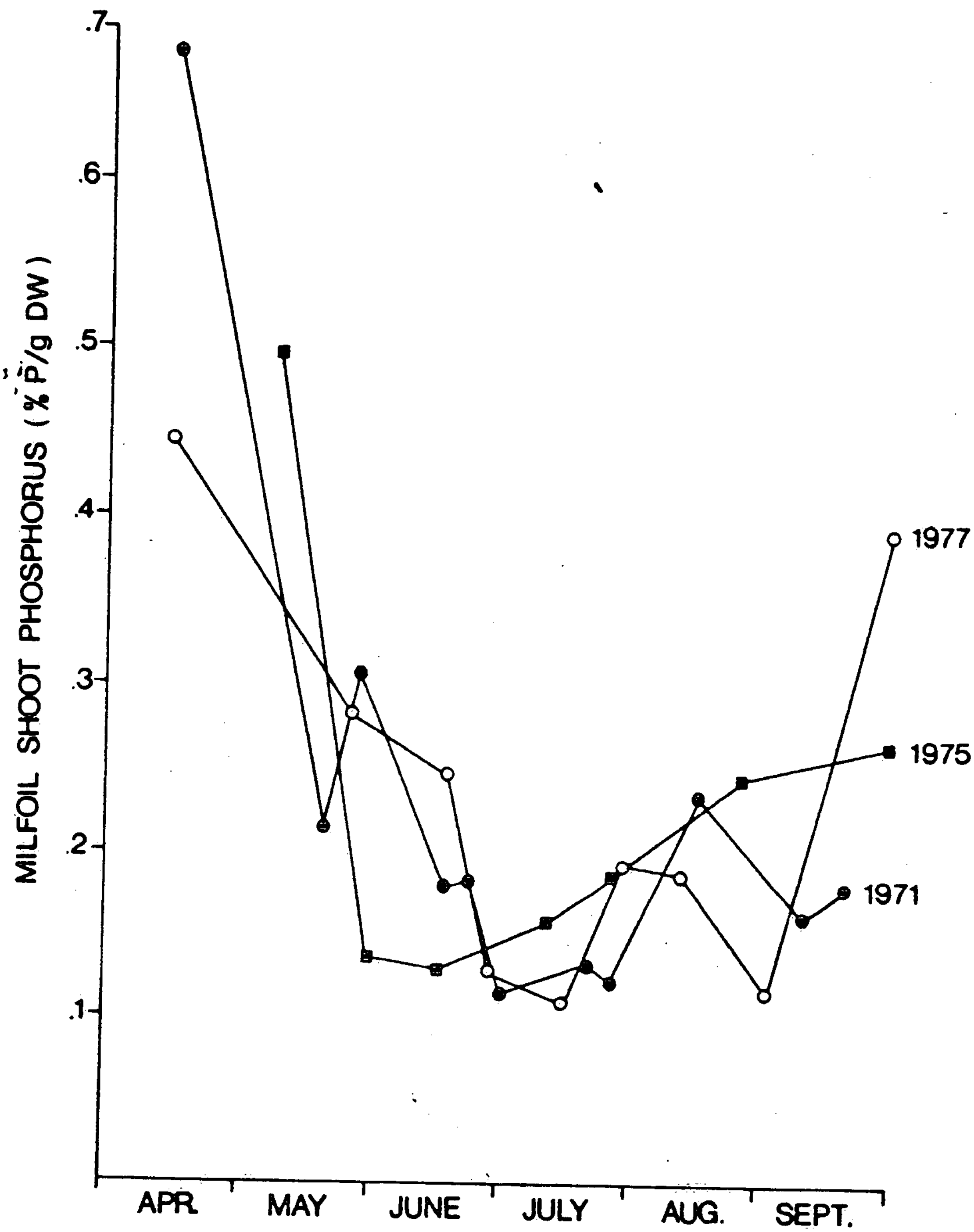
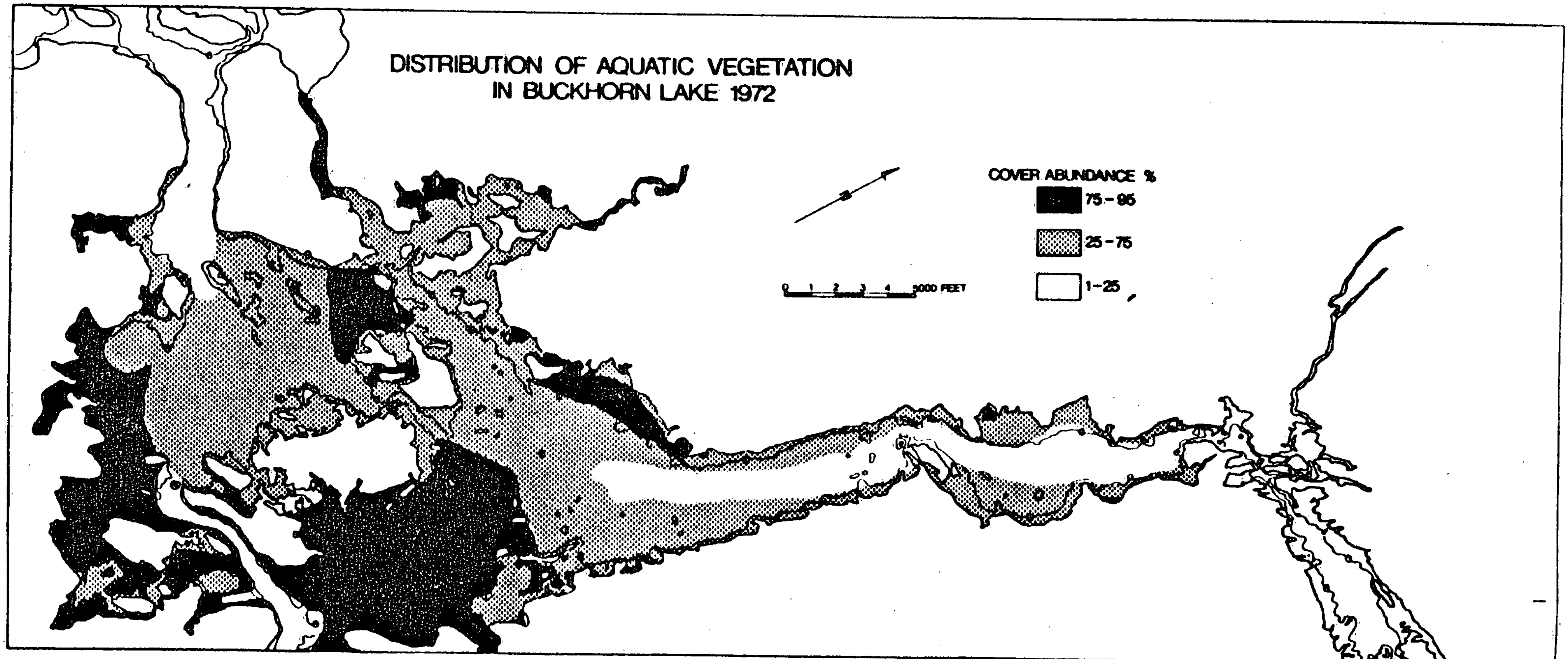
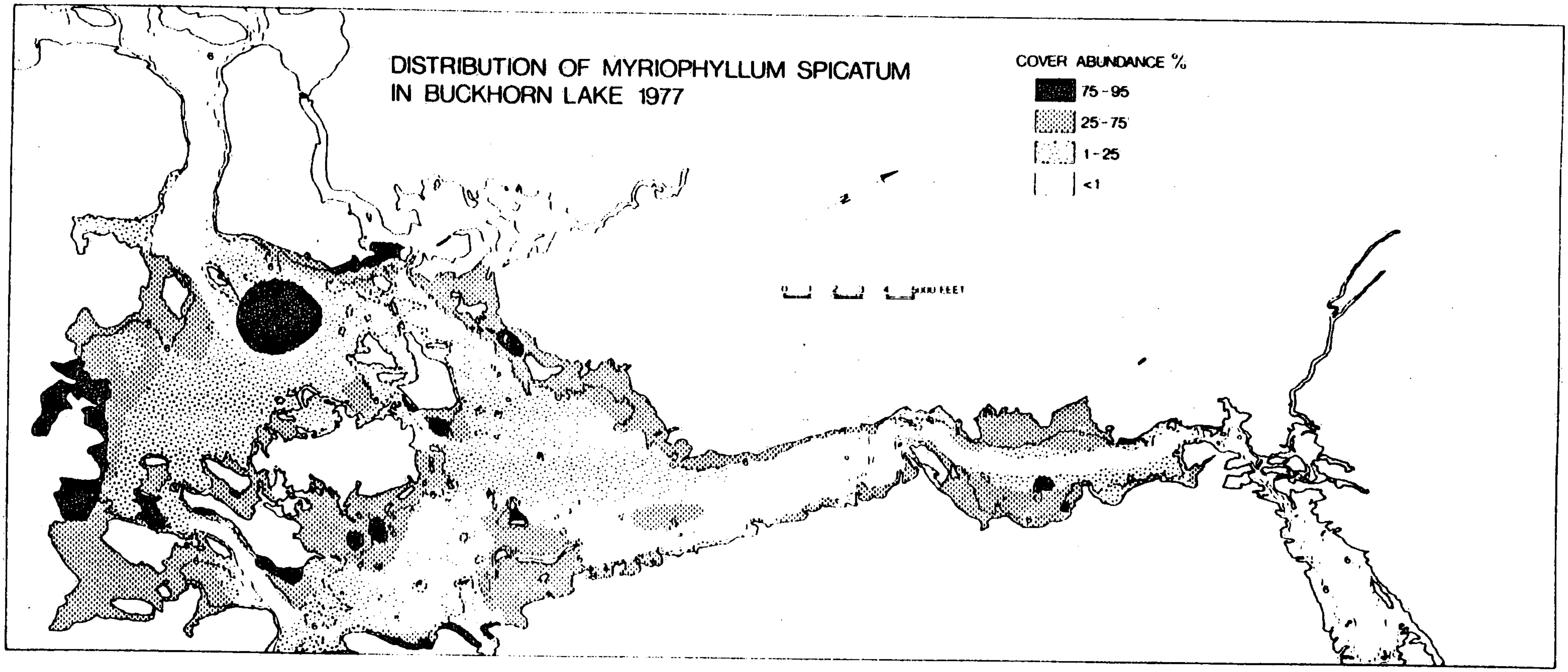
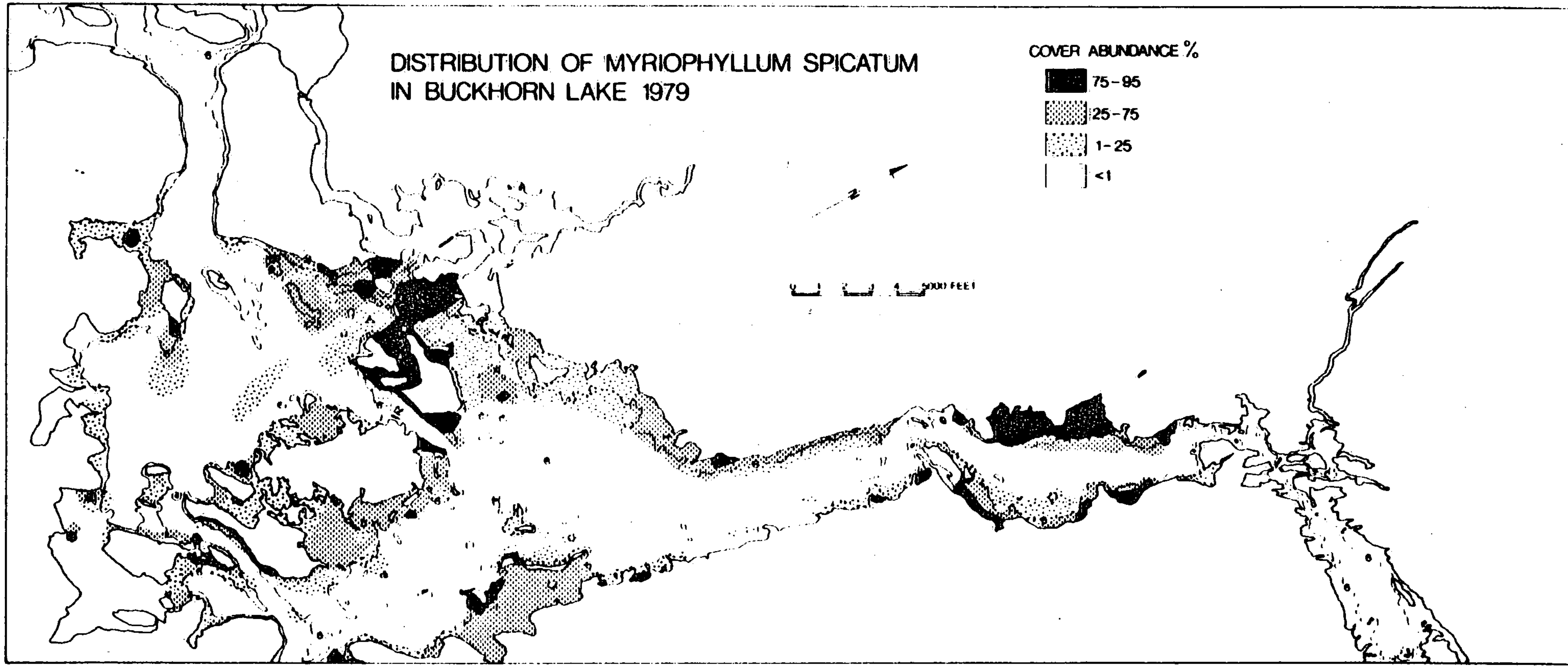

MILFOIL SHOOT PHOSPHORUS (% P/g DW)
.7
.6
.5
.4
.3
.2
.1
APR.
MAY
JUNE
JULY
AUG.
SEPT.
1977
1975
1971

Figure 5: Distribution and abundance of Aquatic Vegetation in Buckhorn Lake, 1972.

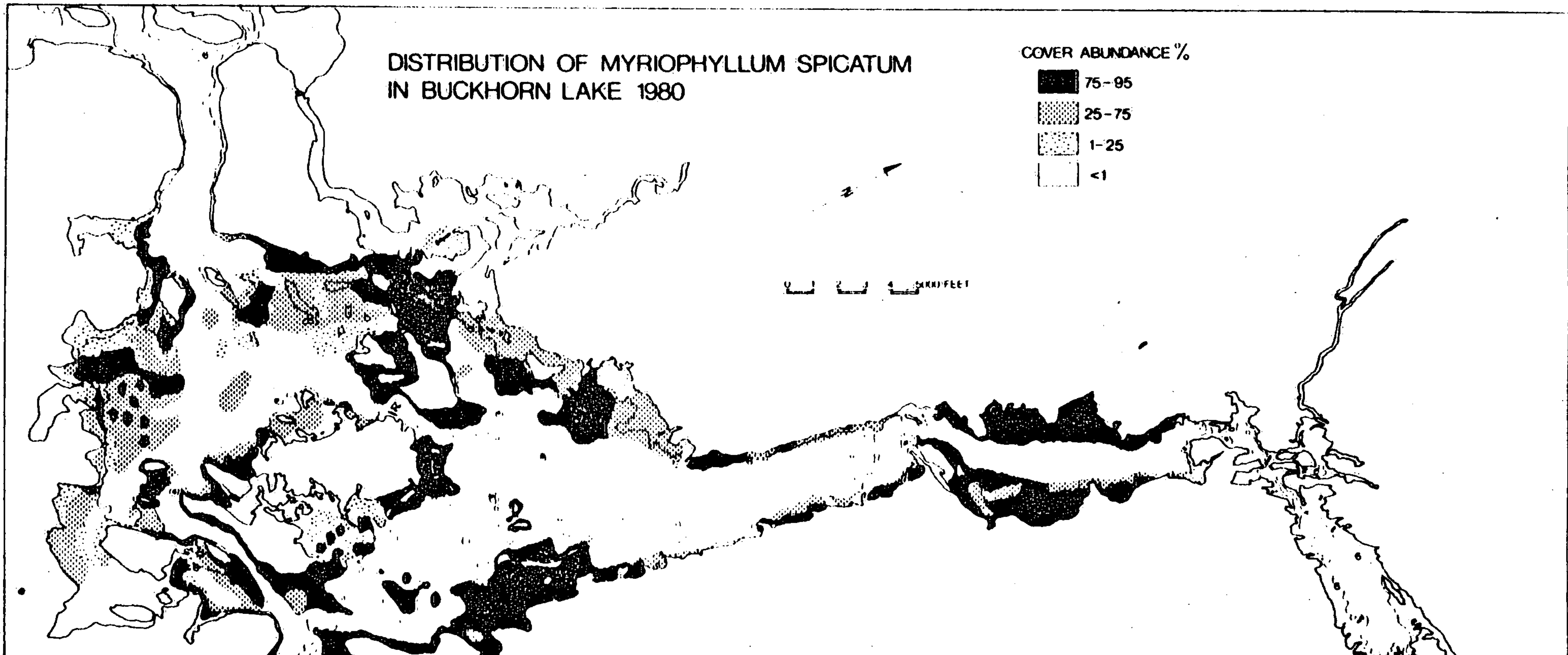
Figures 6-12: Distribution and abundance of milfoil in Buckhorn Lake, 1977,79,80,82,83,84,86.

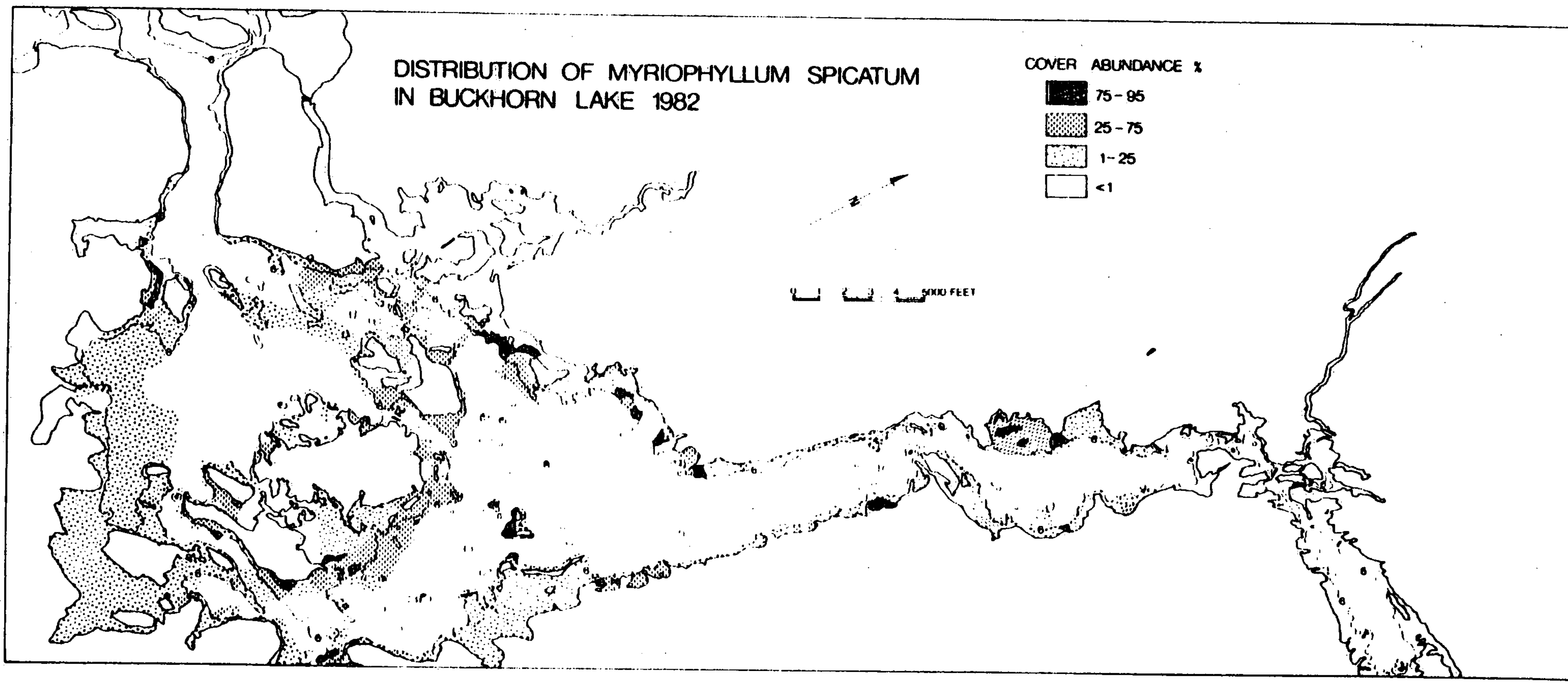

DISTRIBUTION OF AQUATIC VEGETATION
IN BUCKHORN LAKE 1972
COVER ABUNDANCE %
75 - 95
25 - 75
1 - 25
0 1 2 3 4 5000 FEET

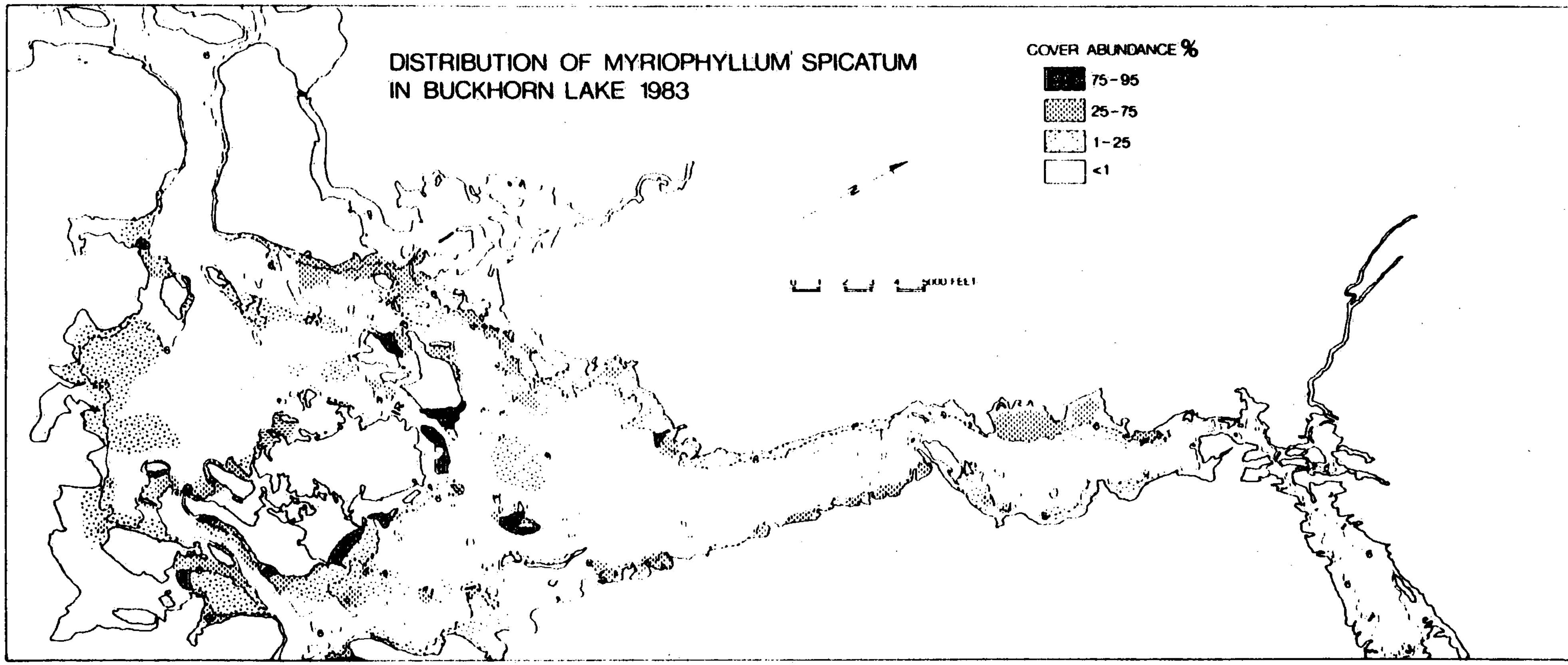

DISTRIBUTION OF MYRIOPHYLLUM SPICATUM
IN BUCKHORN LAKE 1977
COVER ABUNDANCE %
75 - 95
25 - 75
1 - 25
<1



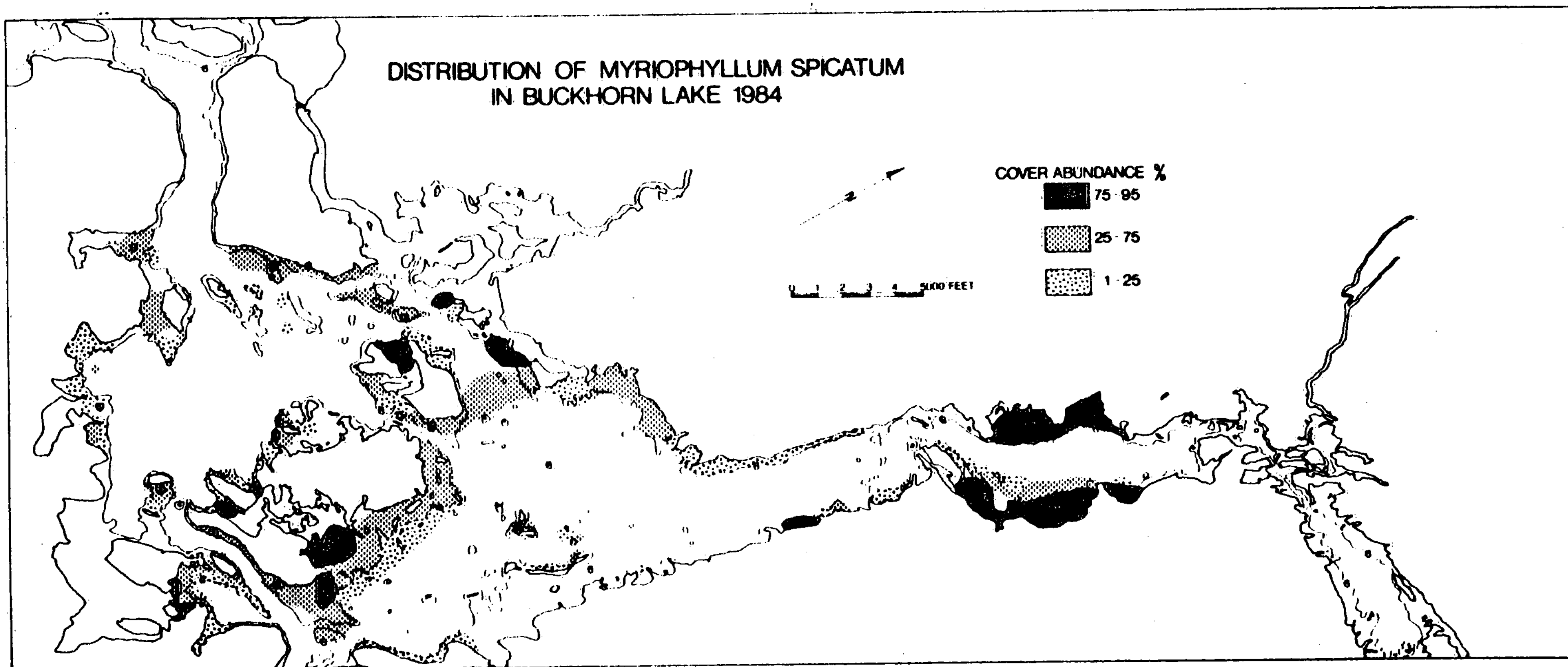
DISTRIBUTION OF MYRIOPHYLLUM SPICATUM
IN BUCKHORN LAKE 1979
COVER ABUNDANCE %
75-95
25-75
1-25
<1


DISTRIBUTION OF MYRIOPHYLLUM SPICATUM
IN BUCKHORN LAKE 1980
COVER ABUNDANCE %
75-95
25-75
1-25
<1


DISTRIBUTION OF MYRIOPHYLLUM SPICATUM
IN BUCKHORN LAKE 1982
COVER ABUNDANCE %
75 - 95
25 - 75
1 - 25
<1
N
5000 FEET


DISTRIBUTION OF MYRIOPHYLLUM SPICATUM
IN BUCKHORN LAKE 1983
COVER ABUNDANCE %
75-95
25-75
1-25
<1
N

DISTRIBUTION OF MYRIOPHYLLUM SPICATUM IN BUCKHORN LAKE 1984



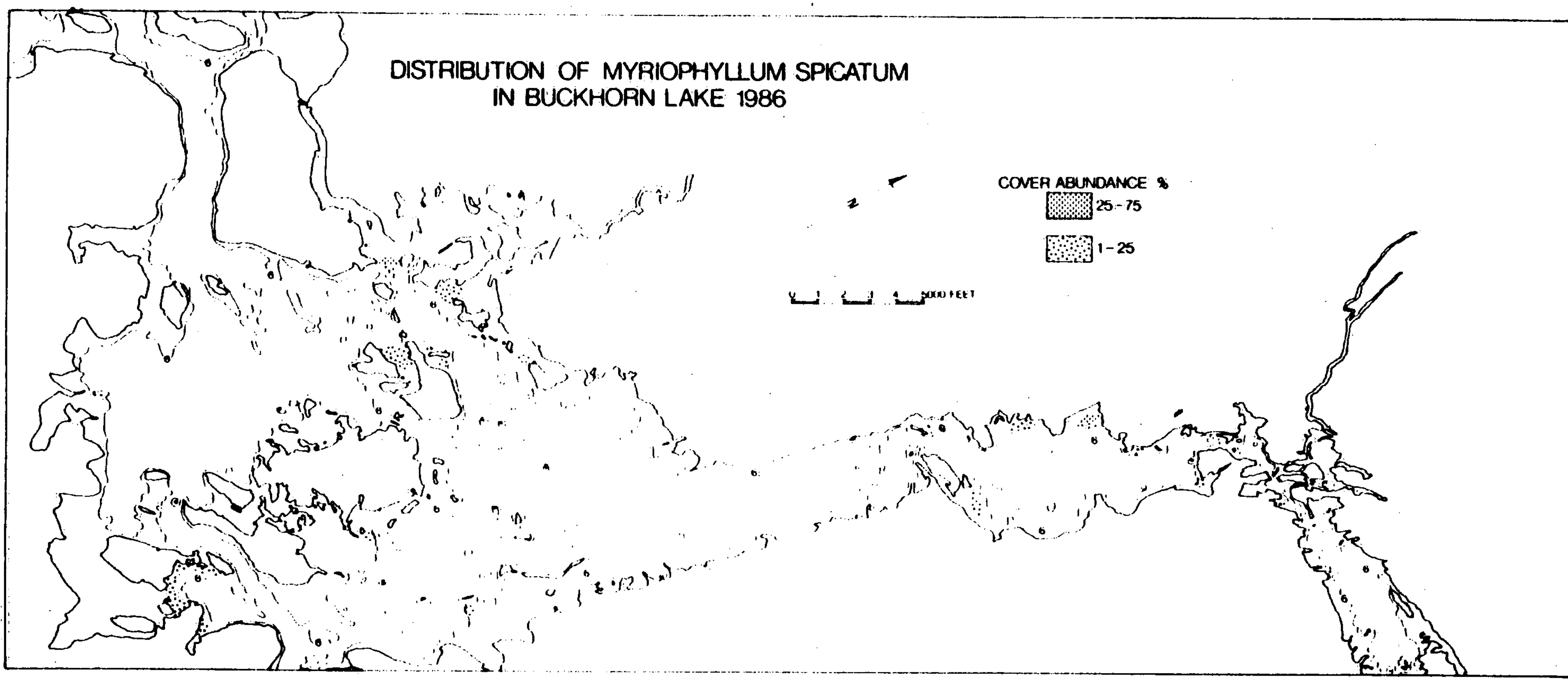
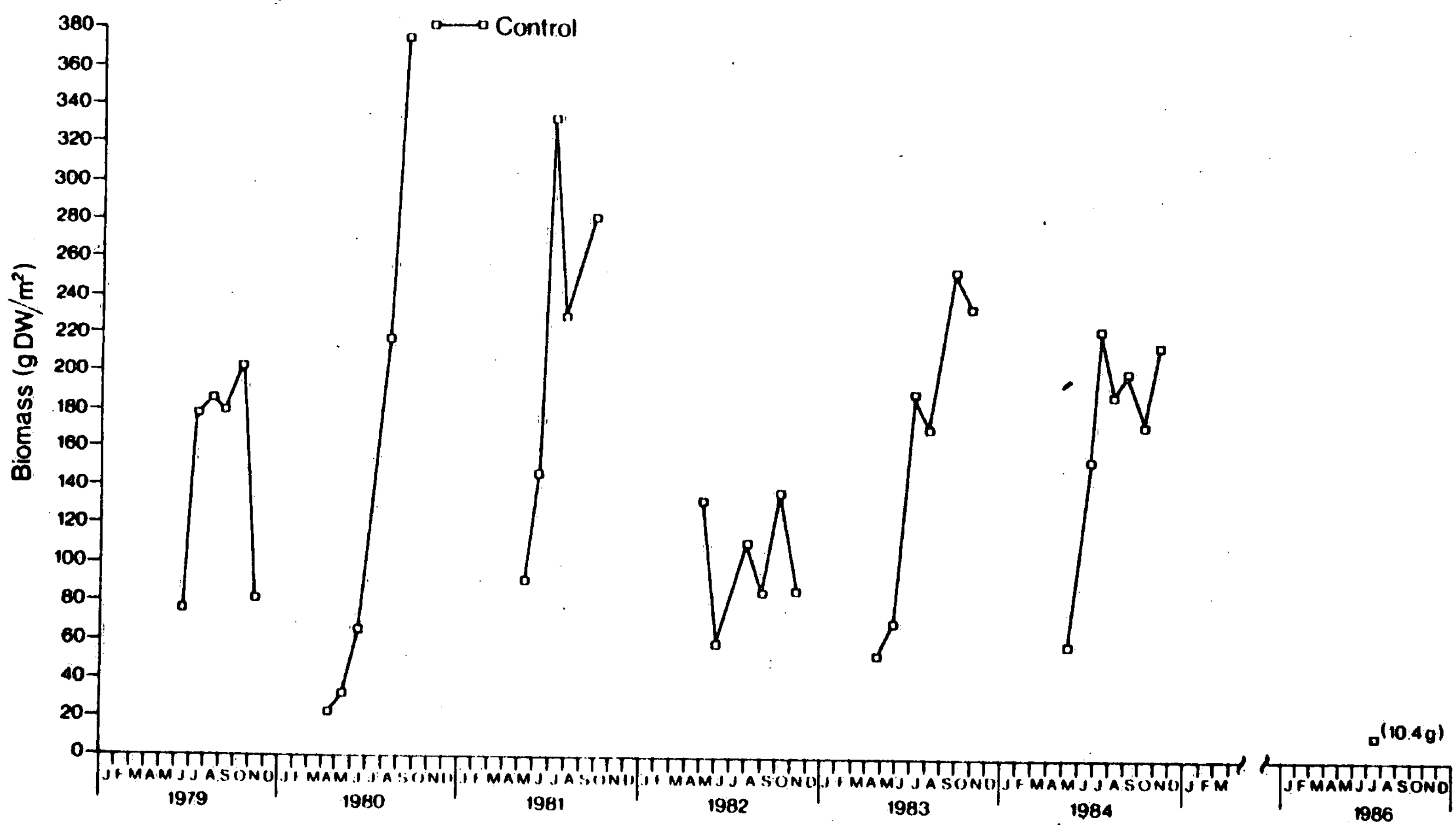

DISTRIBUTION OF MYRIOPHYLLUM SPICATUM
IN BUCKHORN LAKE 1986
COVER ABUNDANCE %
25 - 75
1 - 25
0 1 2 4 5000 FEET
N

Figure 13: Milfoil biomass (g DW/m^2) at Buckhorn Lake site BB1 from 1979 to 1986.

Figure 14: Milfoil shoot phosphorus (ug P/g AFDW) at Buckhorn Lake site BB1 from 1979 to 1984.


Control
Biomass (g DW/m²)
380
360
340
320
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
(10.4 g)
1979
1980
1981
1982
1983
1984
1986

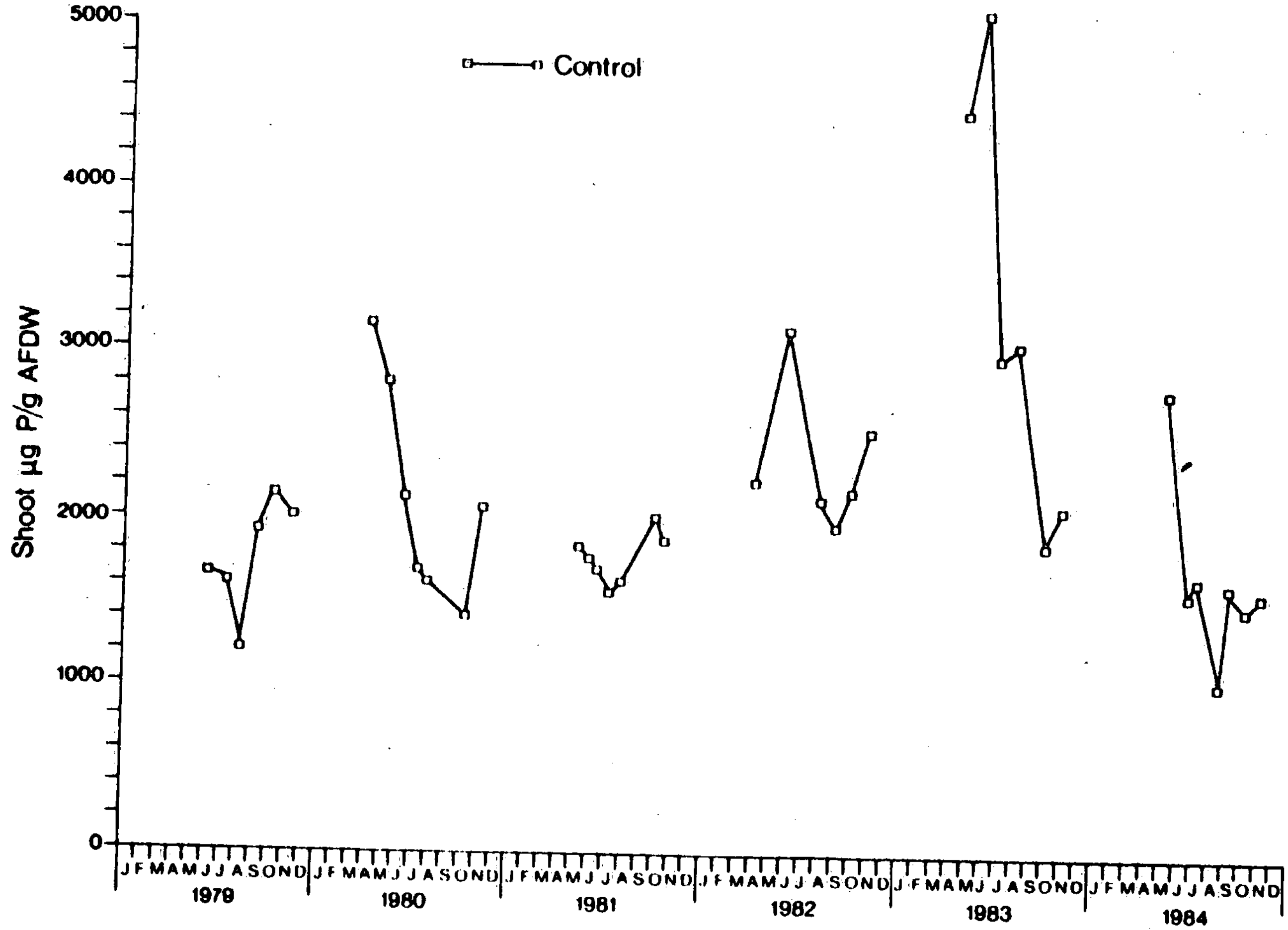

Control
Shoot µg P/g AFDW
5000
4000
3000
2000
1000
0
J F M A M J J A S O N D
1979
1980
1981
1982
1983
1984

Figure 15: Relationship between milfoil dry weight biomass and sediment Eh measured between June 23 and July 7,1980.

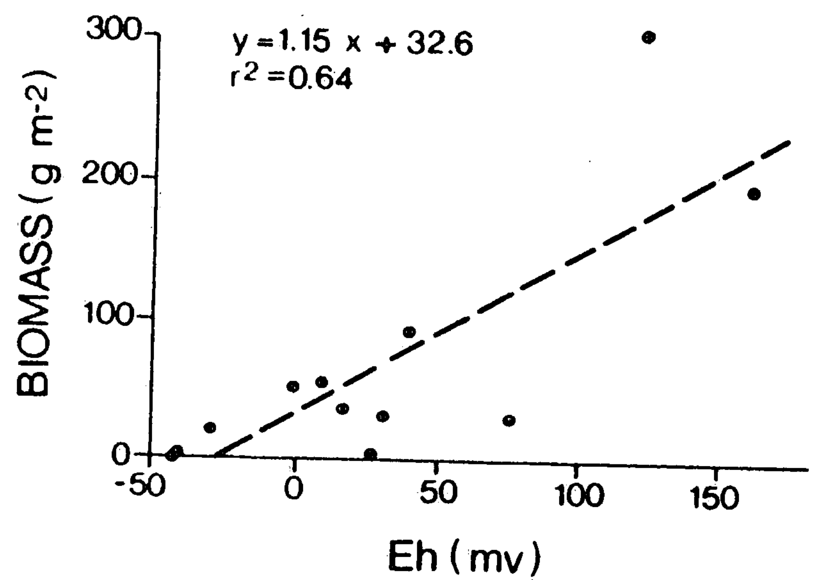

y = 1.15 x + 32.6
r2 = 0.64
BIOMASS (g m-2)
Eh (mv)
300
200
100
0
-50
0
50
100
150

Figure 16: Effect of Iron additions to sediments from one "good" and two "bad" sites on the growth of milfoil expressed as mean fresh weight increment per individual. Error bars represent +/- 1 SE (n=10).

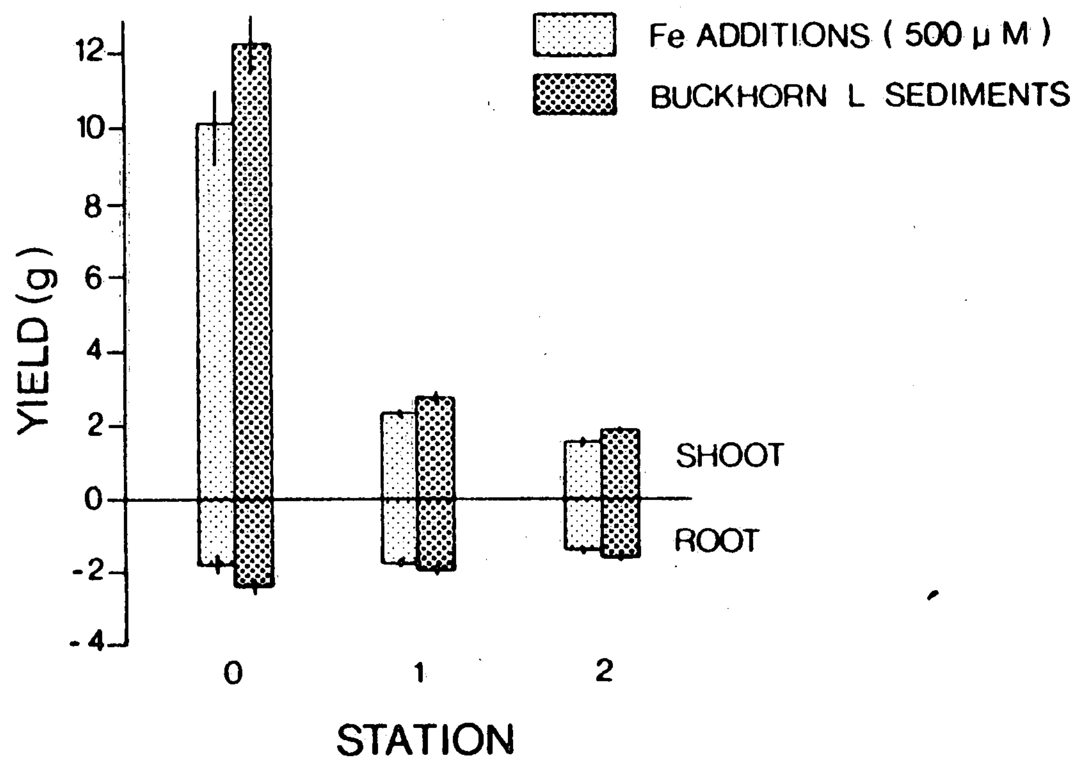

Fe ADDITIONS (500 µ M)
BUCKHORN L SEDIMENTS
YIELD (g)
12
10
8
6
4
2
0
-2
-4
SHOOT
ROOT
0
1
2
STATION

Figure 17: Effect of H_2S additions to the sediments of a "good" site on the growth of milfoil expressed as mean fresh weight increment per individual. Error bars represent +/- 1 SE (n=10).

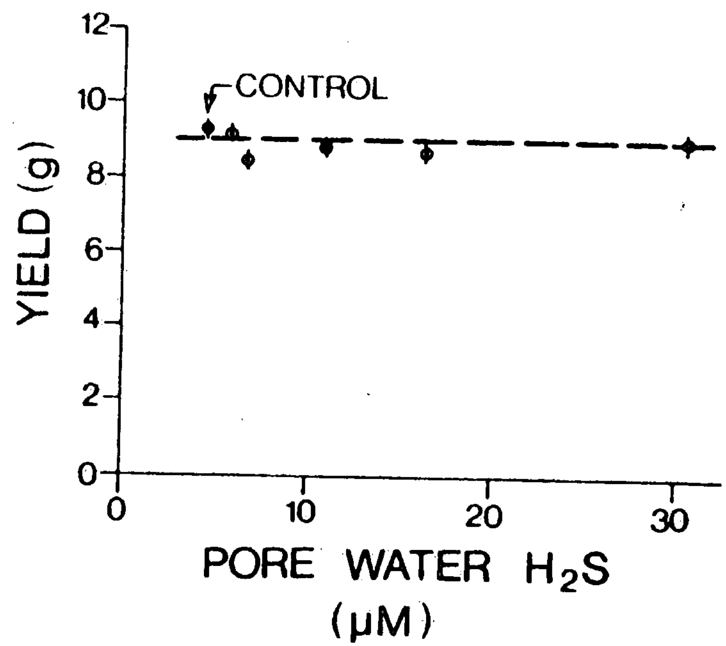

CONTROL
YIELD (g)
12
10
8
6
4
2
0
0
10
20
30
PORE WATER H2S
(μM)

Figure 18: Effect of ammonia additions to the sediment on growth of milfoil expressed as mean fresh weight per individual. Error bars represent +/- 1 SE (n=12).

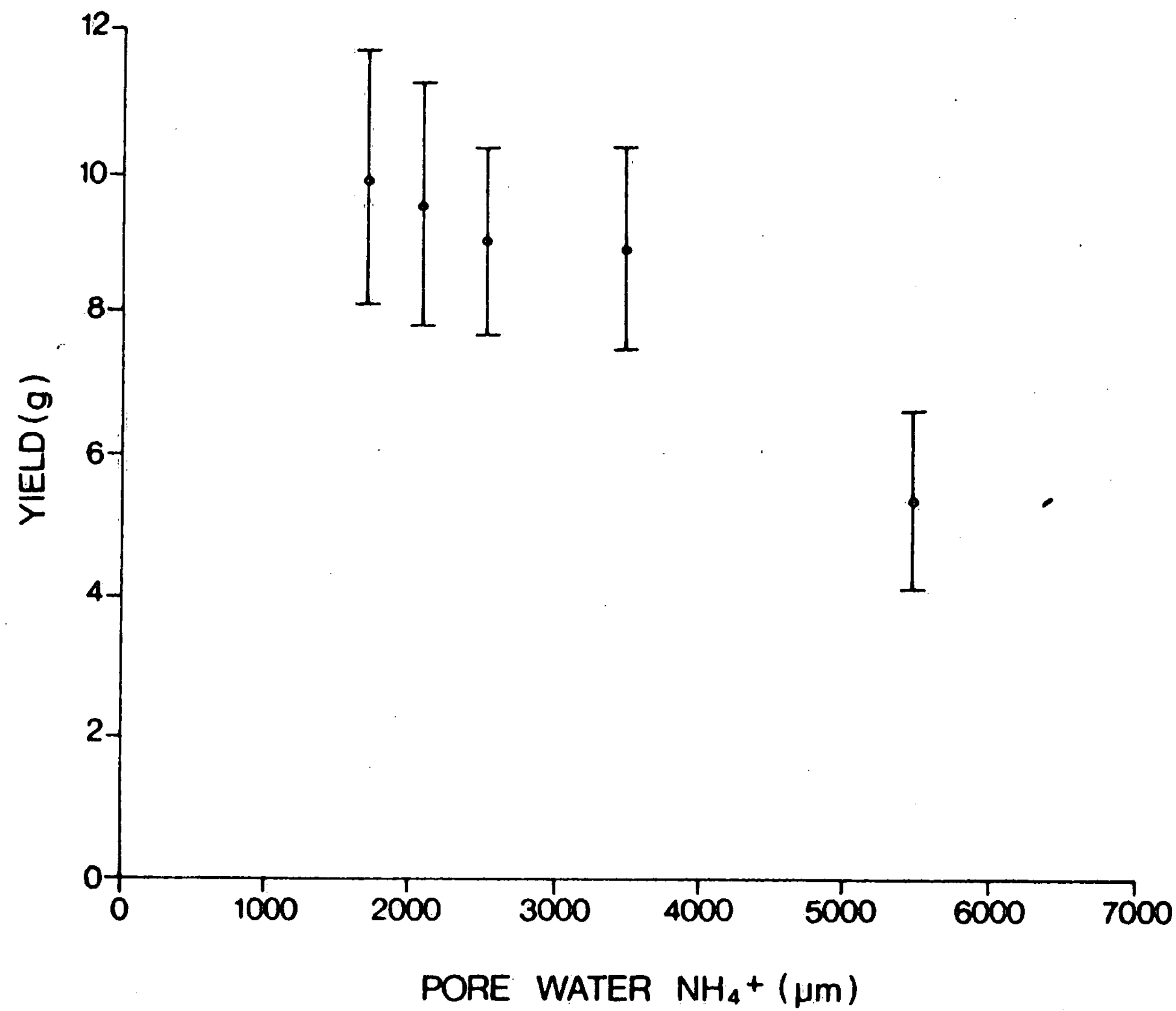
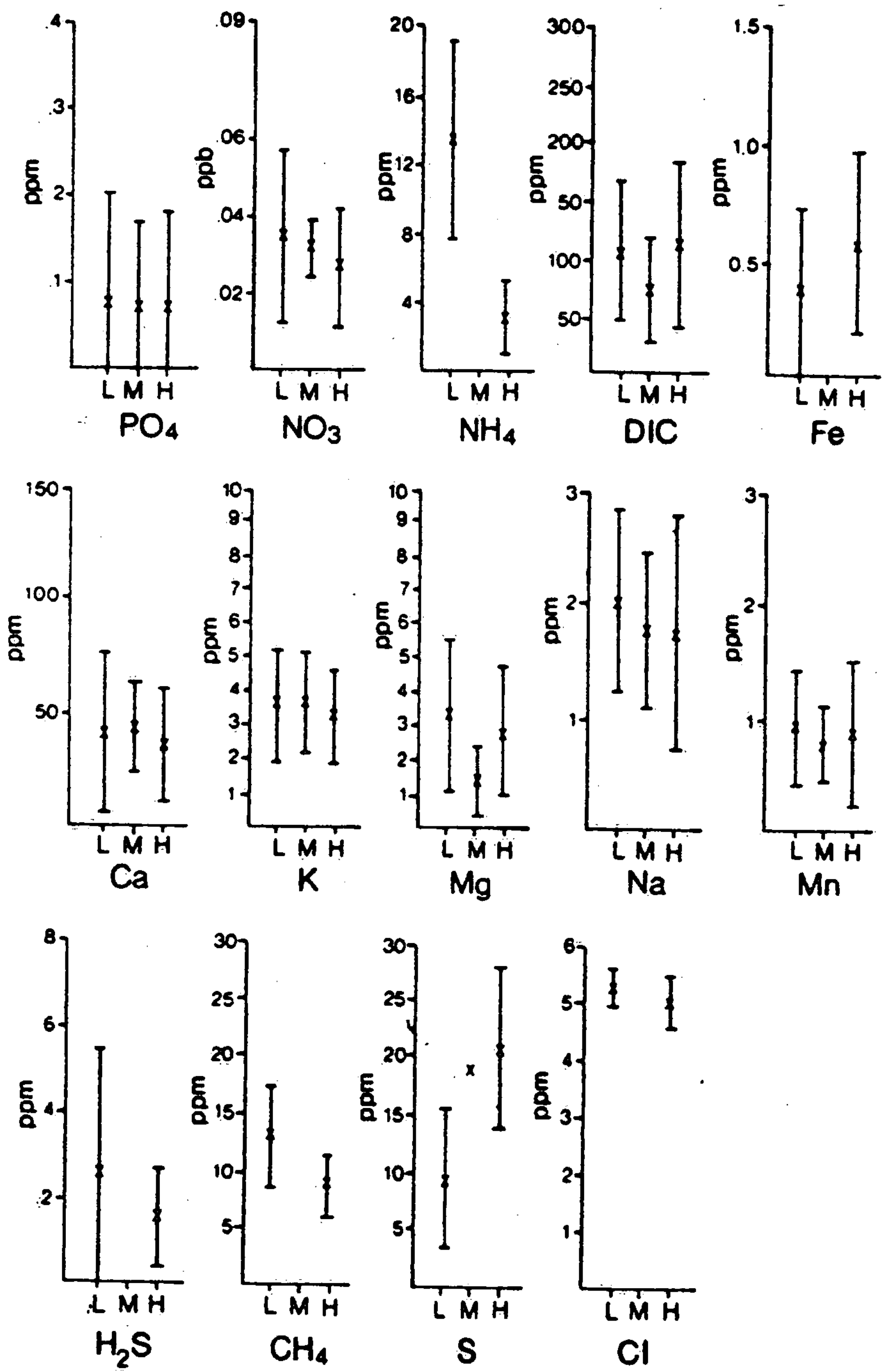
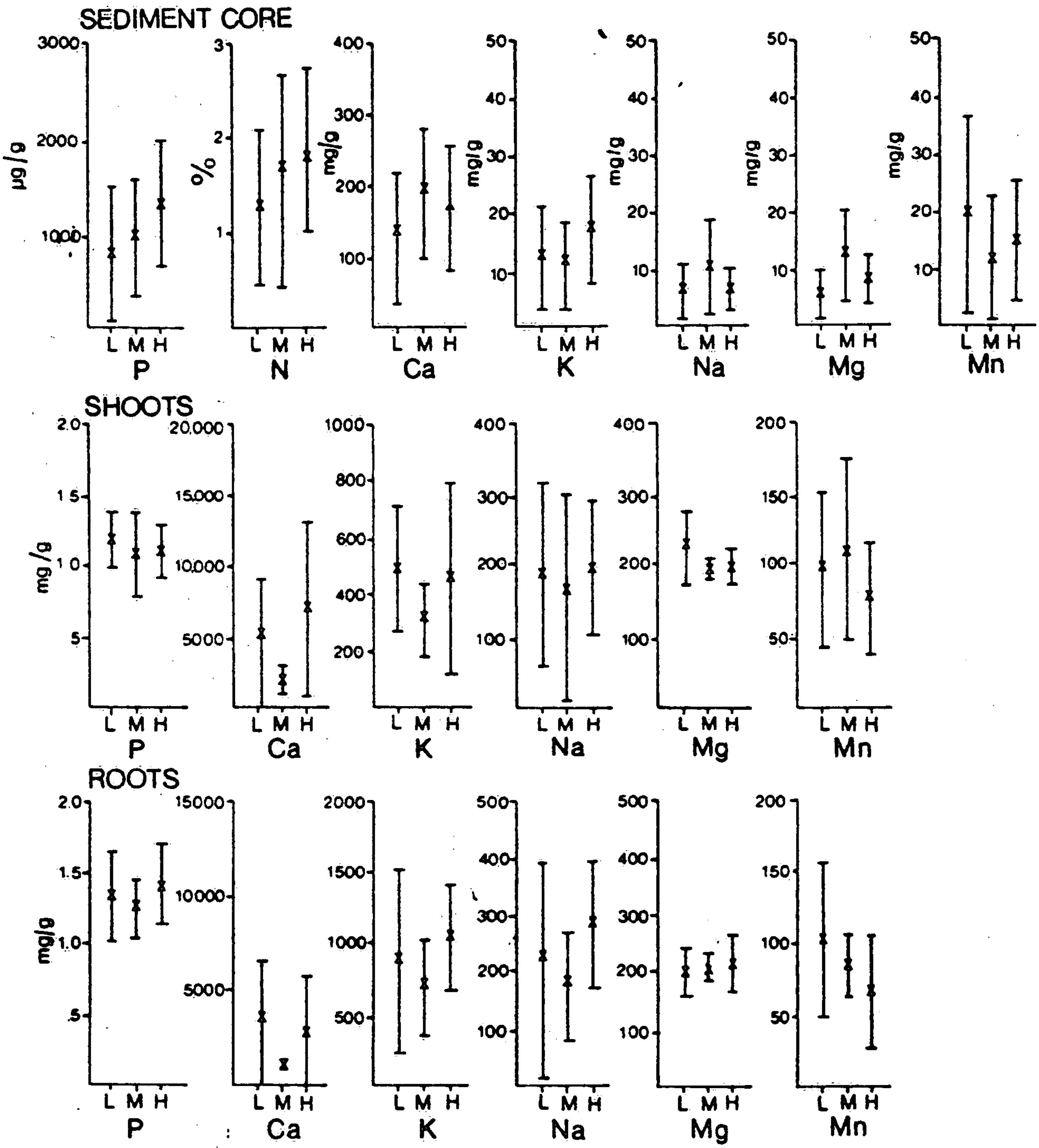

12
10
8
6
4
2
0
YIELD (g)
0
1000
2000
3000
4000
5000
6000
7000
PORE WATER NH4+ (µm)

Figure 19: Sediment Pore Water chemistry from 49 sites in Lakes Buckhorn, Chemung, and Opinicon in three milfoil abundances groupings.

Figure 20: Sediment, shoot, and root chemistry from 49 sites in Lakes Buckhorn, Chemung, and Opinicon in three milfoil abundance groupings.

SEDIMENT PORE WATER CHEMISTRY

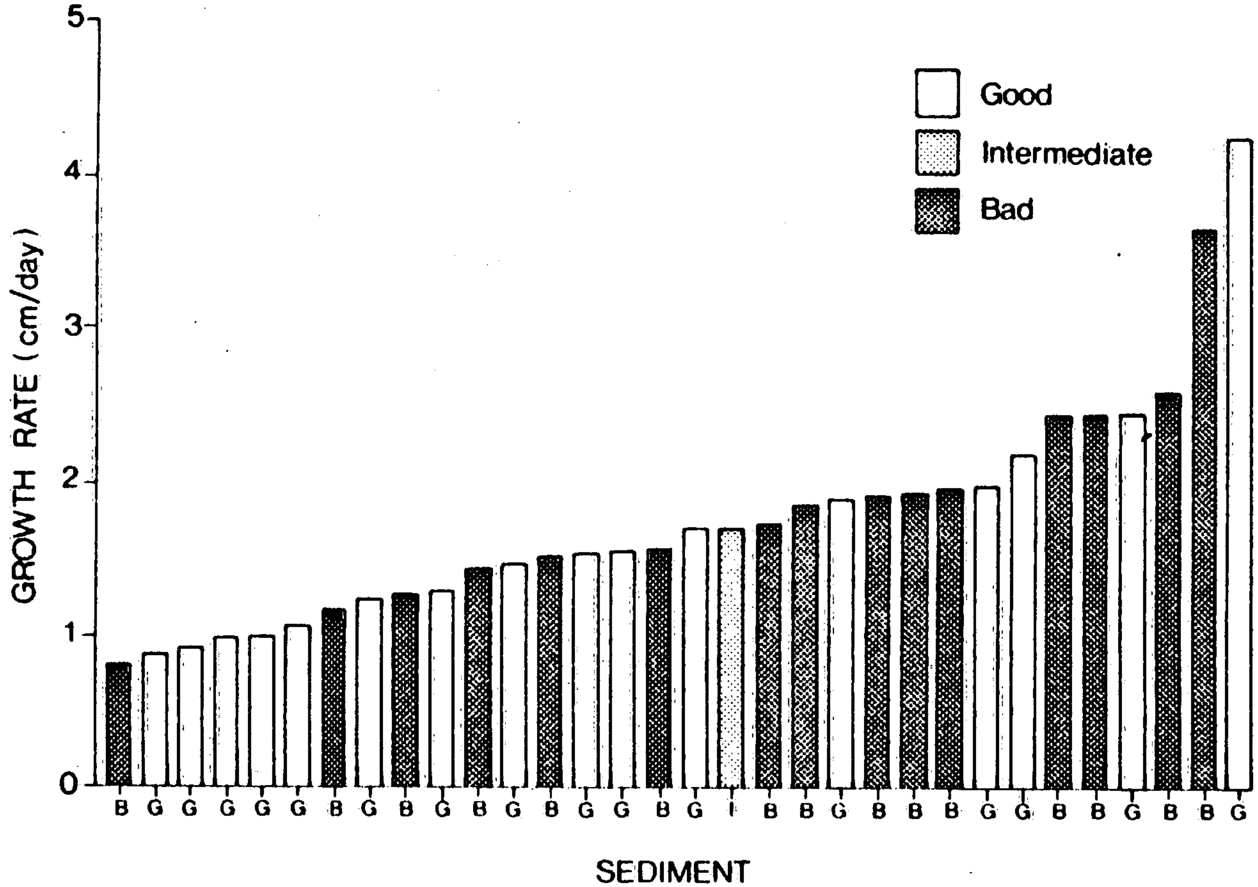


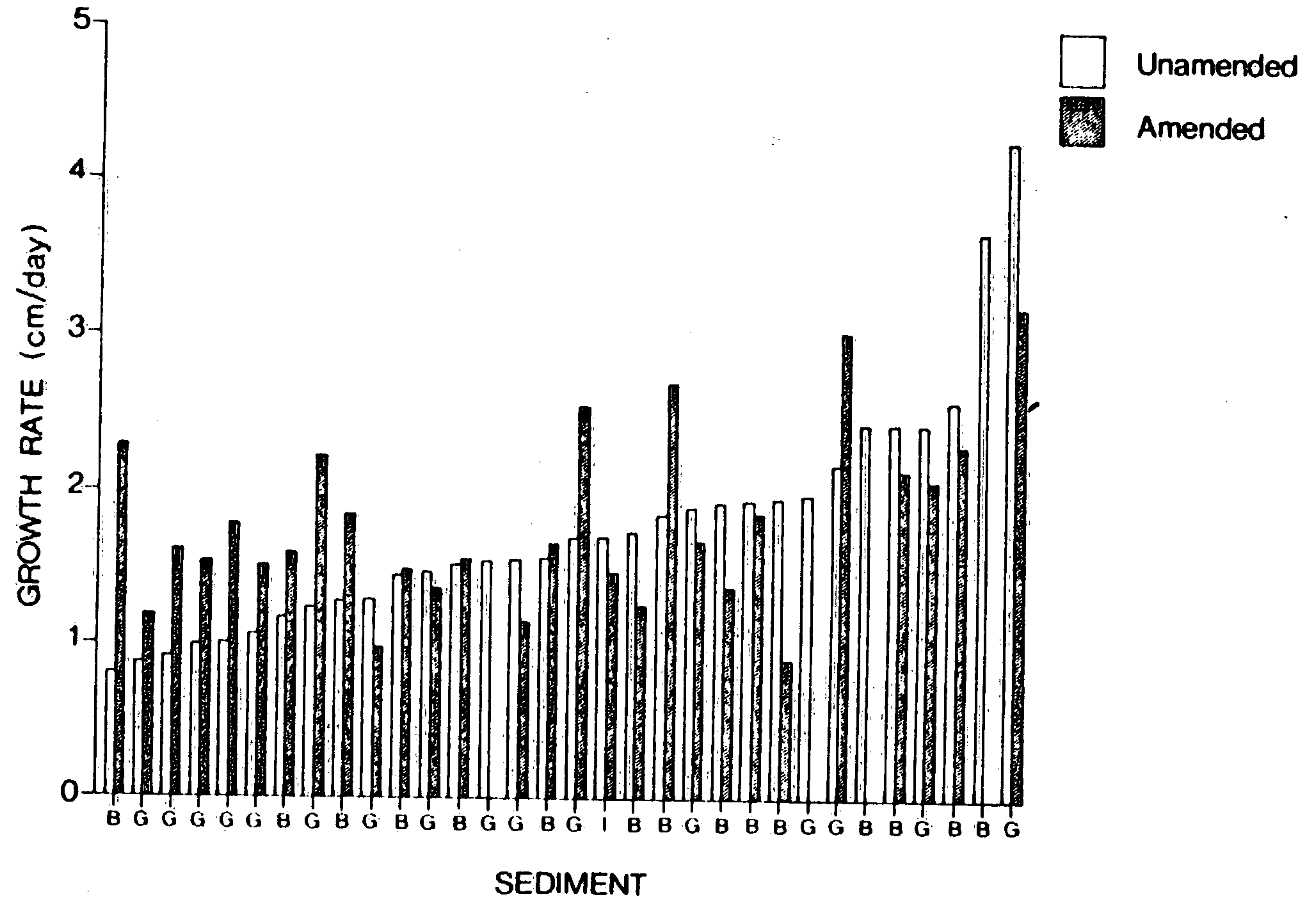


SEDIMENT CORE
µg/g
%
mg/g
3000
2000
1000
3
2
1
400
300
200
100
50
40
30
20
10
L M H
P
N
Ca
K
Na
Mg
Mn
SHOOTS
2.0
1.5
1.0
.5
20,000
15,000
10,000
5000
1000
800
600
400
200
150
100
50
ROOTS
15000
10000
2000
1500
1000
500

Figure 21: Growth rate of milfoil in "good", "intermediate", and "bad" sediments collected from Lakes Buckhorn, Chemung, and Scugog.

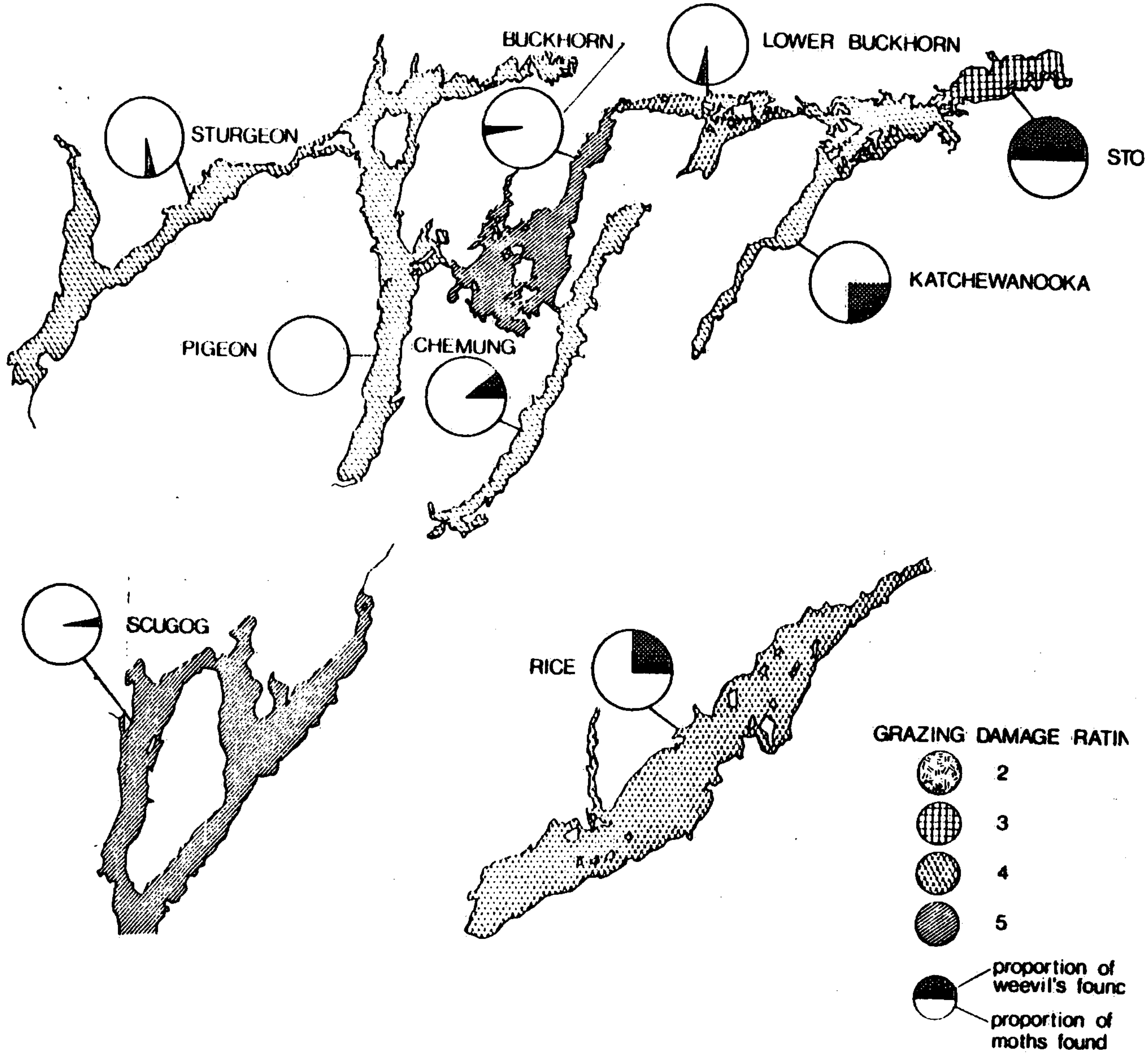
Figure 22: Growth rates of milfoil in "good", "intermediate", and "bad" sediments collected from Lakes Buckhorn, Chemung, and Scugog. Solid bars represent growth rates in the sediments but amended with nutrients.


Good
Intermediate
Bad
GROWTH RATE (cm/day)
0
1
2
3
4
5
B G G G G G B G B G B G B G G B G I B B G B B B G G B B G B B G
SEDIMENT



Unamended
Amended
GROWTH RATE (cm/day)
0
1
2
3
4
5
B G G G G G B G B G B G B G G B G I B B G B B B G G B B G B B G
SEDIMENT

Figure 23-24: Insect grazing damage estimates for several Rideau and Kawartha Lakes and the proportion of weevil larvae versus moth larvae and cases observed.


BUCKHORN
LOWER BUCKHORN
STURGEON
STO
KATCHEWANOOKA
PIGEON
CHEMUNG
SCUGOG
RICE
GRAZING DAMAGE RATIN
2
3
4
5
proportion of weevil's founc
proportion of moths found

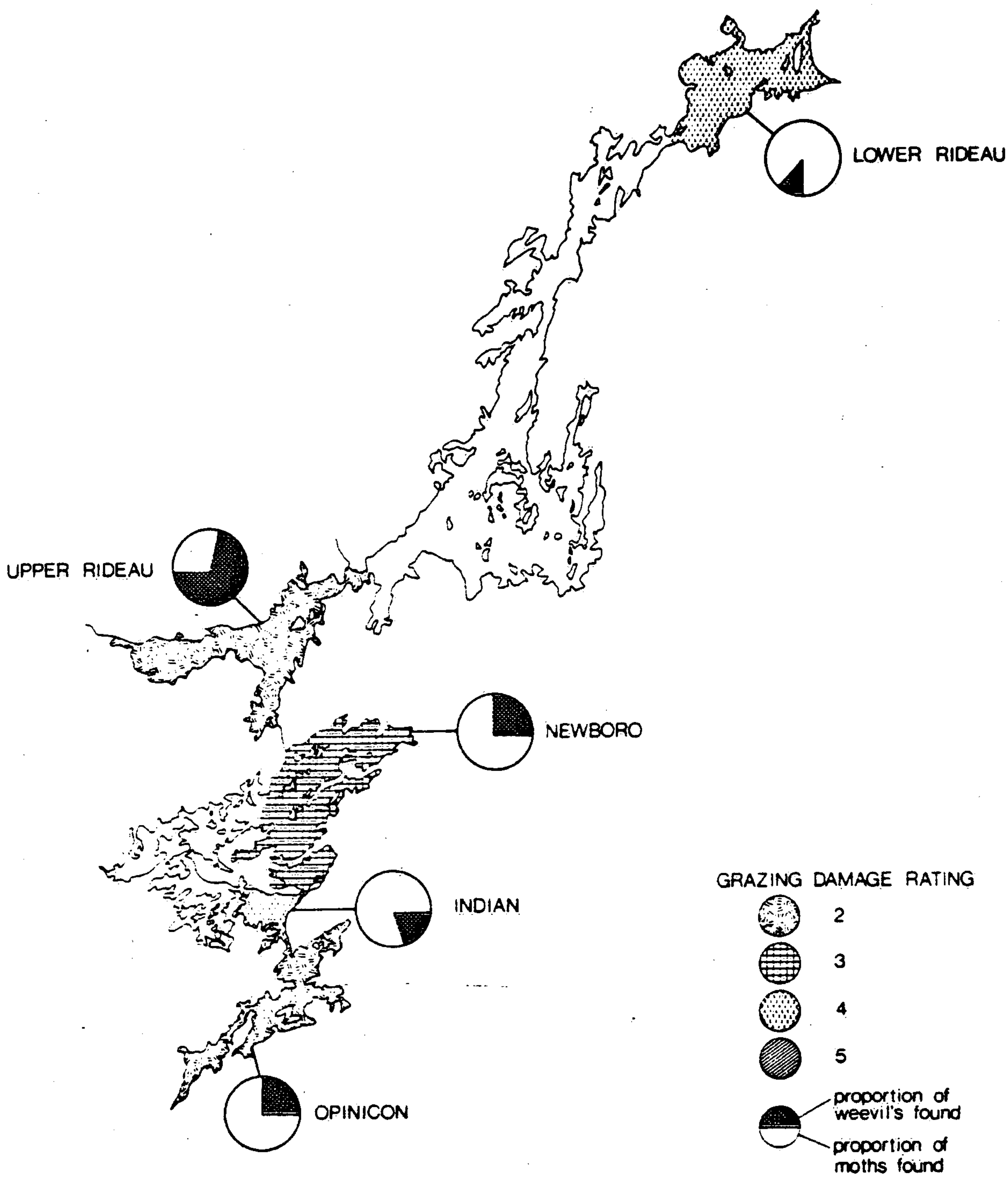
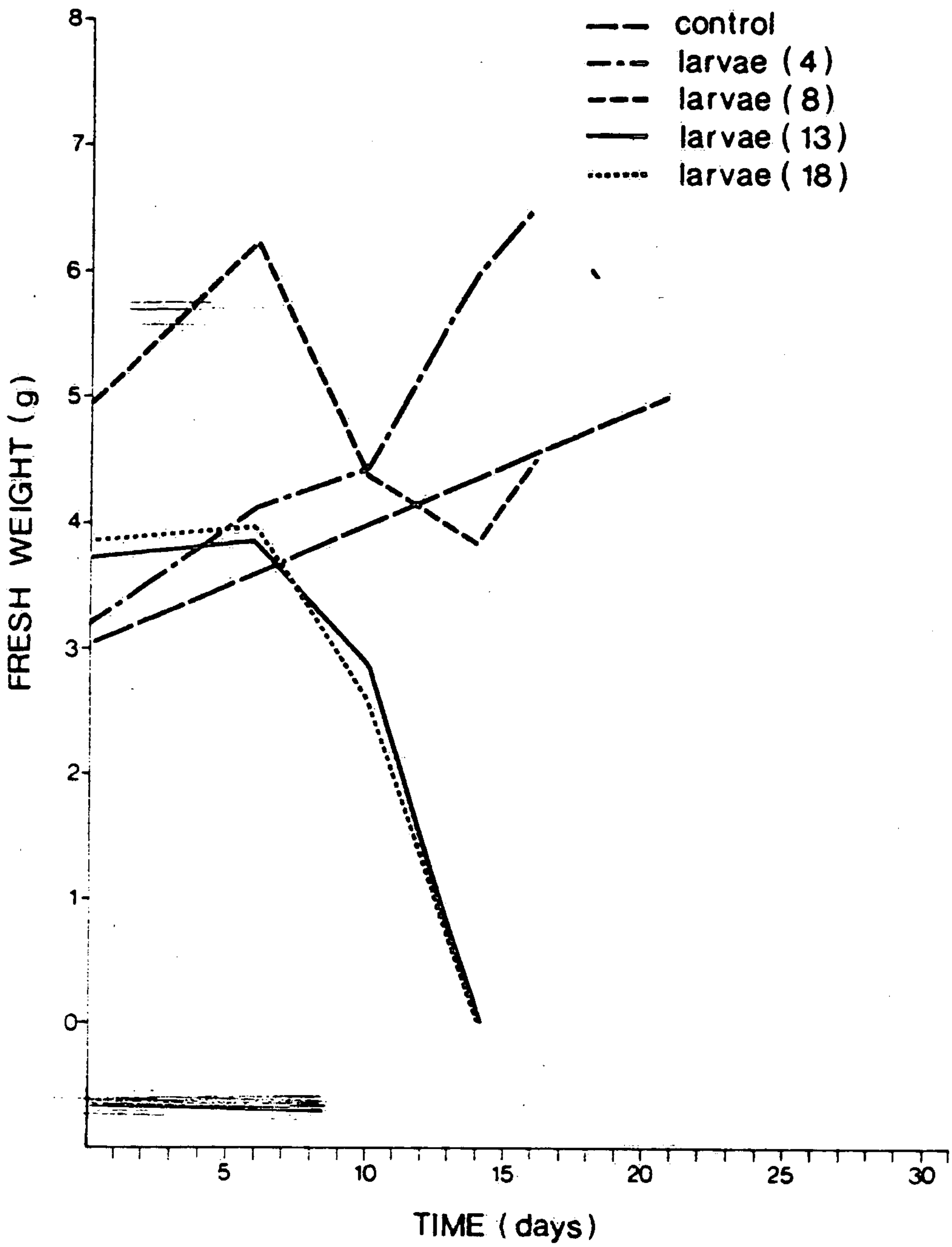

LOWER RIDEAU
UPPER RIDEAU
NEWBORO
INDIAN
OPINICON
GRAZING DAMAGE RATING
2
3
4
5
proportion of weevil's found
proportion of moths found

Figure 25: Fresh weight of milfoil over time grazed upon by varying moth larvae densities.



control
larvae (4)
larvae (8)
larvae (13)
larvae (18)
FRESH WEIGHT (g)
0
1
2
3
4
5
6
7
8
5
10
15
20
25
30
TIME (days)

Table 1: Mean total phosphorus and nitrogen content in milfoil tissues expressed as a percentage of dry weight. (Wile et al., 1979)

Table 2: Areal cover of Eurasian watermilfoil in Buckhorn Lake as a percentage of the total lake's surface from 1972-86.

Table 3: Spring surficial sediment phosphorus fractions (ug/g) from one site in Buckhorn Lake (BB1) from 1979 to 1986. CDB-P is citrate-dithionate-bicarbonate extractable inorganic phosphorus. NaOH-P is 1 N Sodium Hydroxide extractable phosphorus. Apatite-P is 1 N HCl extractable phosphorus. Total P is 1 N HCl extractable phosphorus on an ashed sample. TIP is total inorganic phosphorus. BAP is biologically-available phosphorus extracted with 0.1 N NaOH.

Table 1: Mean total phosphorus and nitrogen content in milfoil tissues expressed as a percentage of dry weight. (Wile et al., 1979)

	1971	1972	1973	1974	1975	1976	1977*
P	.22	.24	.24	.25	.25	.27	.40
N	2.0	2.1	1.8	2.2	2.4	2.3	2.8

* Based on single sampling date.

Table 2: Areal cover of Eurasian watermilfoil in Buckhorn Lake as a percentage of the total lake's surface from 1972-86.

MILFOIL AREAL COVER IN BUCKHORN LAKE

1972	78%
1977	69%
1979	32%
1980	38%
1982	33%
1983	28%
1984	21%
1986	1%

Table 3: Spring surficial sediment phosphorus fractions (ug/g) from one site in Buckhorn Lake (BB1) from 1979 to 1986. CDB-P is citrate-dithionate-bicarbonate extractable inorganic phosphorus. NaOH-P is 1 N Sodium Hydroxide extractable phosphorus. Apatite-P is 1 N HCl extractable phosphorus. Total P is 1 N HCl extractable phosphorus on an ashed sample. TIP is total inorganic phosphorus. BAP is biologically-available phosphorus extracted with 0.1 N NaOH.

	CDB-P C	NaOH-P C	Apatite-P C	Total P C	TIP C	BAP C
1979	89.9	23.4	140.3	1113.2	415.5	
1980	49.4	77.6	105.0	1175.9	360.8	
1981	317.7	84.7	102.9	1581.3	498.9	212.4
1982	176.4	80.6	110.1	1542.6	394.9	182.9
1983	94.7	73.6	74.5	1565.7	422.0	452.5
1984	329.6	89.5	105.0	1262.0	430.9	303.0
1986				1500	450	

Appendix 1: Observations and data from Growth Experiment with "good" and "bad" sediments

Appendix 2: Sediment, pore water, shoot, and root chemistry from 49 sites grouped according to milfoil abundance.

Appendix 3: Observations and data from vermiculite, sawdust and charcoal experiment.

Appendix 4: Observations and data from insect grazing survey.

Appendix 1: Observations and data from Growth Experiment with "good" and "bad" sediments

SITE CODE	LOCATION DESCRIPTION	% COVER ABUNDANCE	BIOMASS SHOOTS	(g/m2) ROOTS	SECCHI (m) (July 2)	LIGHT MEASUREMENTS
BI	east of Curve Lake Indian Reserve	July 2:5-25	22.4	12	1.4	
BG1	Harrington Bay	July 2:75-95	224	17.6	1.6	
BG2	Sandy Creek Bay	July 2:75-95	214	55.6	1	0m-117, 0.5m-79 1m-47
BG3	between Nicholls Pt. and Brown Pt.	July 2:75-95	80	9.6	2	
BB1	Nichol Island	July 2:rare	10.4	5.6	1.75	
BB2	between Chief Is. & Kawartha Hideaway	July 2:0	23.6	12.4	2	0m-160, 1m-65 2m-16
BB3	SE of Curve Lake Indian Reserve	July 2:0			1.4	0m-110,0.5-65 1m-30,1.4m-15
BB4	Boyd Island	July 2:0			1.7	0m-110, 1m-33 1.5m-17,1.7m-8
CG1	SW Shore of Birch Island	July 2:50-75	96.8	62.8	1.5	0m-120,1m-55 1.5m-25
CG2	N of Birch Is.,across from public beach	July 2:25-50	93.6	16.8	1.5	0m-120, 0.5m-80 1m-50, 1.5m-14
CG3	Chemong Narrows	July 2:75-95	154.4	56.4	1.4	0m-110,1m-35 1.5m-14
CB1	Telford Bay	July 2:rare			1	0m-110,1m-35 1.5m-17,1.7m-10
CB2	W of Stewart Hts, near islands	July 2:0			1	0m-110,0.5m-60 1m-30
CB3	S of Heron Is.	July 2:0			1	0m-100,0.5m-55 1m-35
SG1	Nonquon River	July 2:50-75 Sept 18:<25	34.8	58	1	0m-110,1m-25
SG2	Newman's Beach	July 2:50-75 Sept 18:0	116.8	106	1.2	0m-110,1m-25
SG3	King's Bay	July 2:75-95 Sept 18:25-50	162.6	117.4	1.2	0m-105,1m-17 1.5m-4.5
SG5	King's Bay (NE of SG3)	July 2:75-95 Sept 18:0			1.2	0m-105,1m-17 1.5m-4.5
SB3	S of Newman's Beach	July 2:0 Sept 18:0	0	0	1	0m-130,1m-24 1.5m-10
SB4	Highland Beach	Sept 18:75-95				
SB5	across from Patten Is. (west shore)	Sept 18:0				

S E D I M E N T

SITE CODE	pH	Eh	%LOI	Density (g/ml)	DOC (mg/l)	TIP (ug/g)	TP (ug/g)	PART. C	PART. N
BI	6.5		51.1	.06		400	1200	26.3	2.56
BG1	6.4	-140	51.2	.06		470	1200	37.8	2.94
BG2	6.3		40.8	.08		360	1000	41.3	3.41
BG3			53.6	.05		330	1300	29.6	2.85
BB1	6.8	-170	50.3	.07		450	1400	28.8	2.59
BB2	6.2	80	48.5	.07		280	1100	26.2	2.51
BB3	6.4		53.7	.05		350	1200	27.6	2.48
BB4	6.4		53.4	.07		300	1000	33.7	2.68
CG1	6.3	-620	52.2	.04		420	1100	27.3	2.91
CG2	6.2	-550	34.8	.08		40	600	23.7	1.94
CG3	6.4	-580	45	.05		480	1000	28.7	2.91
CB1	6.4	-580	22.2	.11		310	560	17.8	1.54
CB2	6.6		47.3	.09		240	590	21.6	1.46
CB3	6.4	-660	44	.08		330	720	30.9	2.96
SG1			47.2	.1		300	845	39.6	3.09
SG2			63.9	.06		170	840	38	2.91
SG3		-221.	33.5	.07714	17.87	240	676.7	23.2	1.95
SG5			36.4	.075		380	460	29.8	3.48
SB3		-284	38.3	.07429	17.37	430	880	26.5	2.28
SB4			42.8	.085		160	350	34.2	2.77
SB5			29.3	.09		330	750	24.4	2.09

UNAMENDED SEDIMENT
EXPERIMENT 1

SITE CODE	REPS	AV SHOOT DAY17	LENGTH (cm) DAY 37	GROWTH RATE (cm/day)
BI	10	16.95	51.2	1.71
BG1	10	27.75	71.39	2.18
BG2	13	21.85	51.5	1.48
BG3	7	10.71	35.57	1.24
BB1	10	19.25	56.38	1.86
BB2	16	15.25	44	1.44
BB3	6	34.5	73.56	1.94
BB4	12	11.71	27.79	.8
CG1	13	14.69	34.58	.99
CG2	12	19.58	50.92	1.57
CG3	12	10.17	27.58	.87
CB1	12	17.08	55.42	1.92
CB2	9	22.67	71.72	2.45
CB3	13	9.85	33.27	1.17
SG1	12	8.38	29.71	1.07
SG2	14	8.43	34.25	1.29
SG3	13	7	26.58	.98
SB3	11	21.82	61.23	1.97

AMENDED SEDIMENT
EXPERIMENT 1

REPS	AV SHOOT DAY17	LENGTH (cm) DAY 37	GROWTH RATE (cm/day)
6	14	43.4	1.47
11	17.95	78.64	3.03
12	17.64	44.93	1.36
20	21.93	66.3	2.22
13	26.73	80.46	2.69
13	22.46	52.31	1.49
13	11.62	48.7	1.85
11	22.59	68.35	2.29
12	17.21	53.05	1.79
10	15.25	38.3	1.15
10	10.65	34.45	1.19
12	13.79	41.29	1.38
11	14.32	57.1	2.14
13	14.65	46.58	1.6
12	12.08	42.23	1.51
13	12.15	31.62	.97
13	15.62	46.5	1.54
11	8.55	26.5	.9

UNAMENDED SEDIMENT
EXPERIMENT 2

	REPS	AV SHOOT t0 DAY 0	LENGTH (cm) t1 DAY 16	t2 DAY 37	GROWTH RATE (cm/day) t1-t0/16	t2-t1/21
SG1	10	10	40.45	130.25	1.9	4.28
SG3	10	10	49.2	84.85	2.45	1.7
SG5	10	10	34.6	76.2	1.54	1.98
SB3	15	10	49	126.3	2.44	3.68
SB4	10	10	35.05	89.4	1.57	2.59
SB5	10	10	37.8	69.85	1.74	1.53

AMENDED SEDIMENT
EXPERIMENT 2

REPS	AV SHOOT LENGTH (cm) t0 DAY 0	t1 DAY 16	t2 DAY 37	GROWTH RATE (cm/day) t1-t0/16	t2-t1/21
5	10	36.8	103.9	1.68	3.2
10	10	43.3	96.9	2.08	2.55
10	10	36.5	85	1.66	2.31
10	10	30	62.8	1.25	1.56

LAKE SCUGOG GOOD SITE #3 - UNAMENDED

PLANT	TOTAL SHOOT LENGTHS (cm) DAY 0	DAY 7	DAY 14	DAY 21	DAY 29	DAY 36	AV ROOT WT (g)	AV SHOOT WT (g)
1	7.2	18	24	33	38	42		
2	11.2	22	30	37	40	42.5		
3	6	16.5	21	23	24	26		
4	9.5	23	25	27	39.5	44	.28	.51
5	7	14.5	21	28.5	35.5	40.5		
6	13	17	34	40	45.5	54		
7	12.2	20	34	45	56	66		
8	14.5	20	30.5	42	49.5	62.5	.27	.55
9	12	24	30	33	37	40.5		
10	22	31.5	37.5	55.5	68	86		
11	8	19.5	32	43	54.5	57		
12	12	19.5	26	34	47	49	.33	.83
13	8.5	10	14	19	22	23		
14	19	26.5	35	48	56.5	62		
15	8	20	28.5	34	37.5	40.5		
16	7.5	13	17	20	21	22.5	.2	.5
17	4	9	14	19	22	23		
18	10	12	17	21.5	25	26		
19	5	14	20	23	24	24		
20	11	16	22	27	29.5	30		
AV LENGTH	10.38	18.30	25.63	32.63	38.60	43.05	.27	.60
GROWTH RATE (cm/d)		1.13	1.05	1.00	.75	.64		

OVERALL GROWTH RATE = 0.91 cm/day

LAKE SCUGOG GOOD SITE #3 - AMENDED

PLANT #	TOTAL SHOOT LENGTHS (cm) DAY 0	DAY 7	DAY 14	DAY 21	DAY 29	DAY 36	AV ROOT WT (g)	AV SHOOT WT (g)
1	12.5	19.5	26	43	62	98		
2	19	23.5	28	49	62	62		
3	8	11	15	23	26.5	38		
4	7	13	23	38	58	95		
5	7	14.5	20	28	42	56.5	.17	.65
6	15	20	32	57	91.5	134		
7	8	13.5	17	25	34	50		
8	9	12	17.5	27	40	50		
9	14	15	19.5	29	49	77		
10	15	18.5	21	26	36	36	.11	.72
11	6	8	11	16	22	24.5		
12	13	19	25	42	66	106		
13	6	11	17	29	43.5	59		
14	9	12	16	28	54	71		
15	8	11	16	26	41	56	.11	.65
16	9	12	16	29	42	64		
17	6.5	14	21	32	71	70		
18	8	11	16	26	39	52		
19	7	12	22.5	39	58	83		
20	6	14	19	31	45	70.5	.1	.67
AV LENGTH	9.65	14.23	19.93	32.15	49.13	67.63	.12	.67
GROWTH RATE (cm/d)		.65	.81	1.75	2.12	2.64		

OVERALL GROWTH RATE = 1.61 cm/day

LAKE SCUGOG BAD SITE #3 - UNAMENDED

PLANT #	TOTAL SHOOT LENGTHS (cm) DAY 0	DAY 7	DAY 14	DAY 21	DAY 29	DAY 36	AV ROOT WT (g)	AV SHOOT WT (g)
1	9	20	29	39	46.5	56		
2	18	26	34	47	67	89		
3	13	20	27	33.5	41	46		
4	8.5	25	29.5	39.5	53	71.5	.26	.82
5	9.8	18.5	24.5	32	33	35		
6	15	28	34.5	49.5	54.5	62.5		
7	13	27.5	38.5	44.5	46	52.5		
8	7	21	26	39	40	41.5	.48	.7
9	9.5	17	26.5	34	45.5	56.5		
10	20.5	26	35	51	69.5	99.5		
11	8	17	24	32	40.5	51.5		
12	8	21	31.5	52	69.5	110	.26	.88
13	13.5	23.5	36	41.5	45.5	47.5		
14	12	21	38	49.5	58	65		
15	12	19.5	27.5	41	48	54		
16	9	20.5	30.5	45	52	54	.41	.71
17	8	13	20	25.5	38.5	43.5		
18	7	15	24	30.5	31	36		
19	10	12.5	16.5	25	28	33		
20	5	9	17	27	28.5	36		
AV LENGTH	10.79	20.05	28.58	39.05	46.78	57.03	.35	.78
GROWTH RATE (cm/d)		1.32	1.22	1.50	.97	1.46		

OVERALL GROWTH RATE = 1.28 cm/day

LAKE SCUGOG BAD SITE #3 - AMENDED

PLANT #	DAY 0	DAY 7	DAY 14	DAY 21	DAY 29	DAY 36	AV ROOT WT (g)	AV SHOOT WT (g)
	TOTAL SHOOT LENGTHS (cm)							
1	26	30.5	36.5	42	56	92		
2	16	21	26.5	44	60	97		
3	8	17	25	38	48	79		
4	8	15.5	23	35	50.5	80		
5	7	12.5	22	35.5	56	75	.16	.94
6	6	8	15	27	46	72		
7	8	16	22	31	45	74		
8	6	11	18	30	48.5	79.5		
9	10	17	25	37	57	91		
10	12	15	18.5	29	45.5	79	.18	.93
11	12	15	20.5	31	50	72		
12	10	17	19	25	37	54		
13	5	7	13	24	40	71		
14	6	14	22	35	57.5	75		
15	7	14.5	20	31	53	75	.14	.66
16	6	6	11.5	26	39.5	53		
17	7	12	21	35	55	84.5		
18	12	16	21	34	61	95.5		
19	8	14	19	31	47	70		
20	7	10	14.5	23	35	43	.11	.68
AV LENGTH	9.35	14.25	20.65	32.18	49.38	75.58	.15	.81
GROWTH RATE (cm/d)		.70	.91	1.65	2.15	3.74		

OVERALL GROWTH RATE = 1.84 cm/day

Appendix 2: Sediment, Pore water, shoot and root chemistry from 49 sites grouped according to milfoil abundance

Sediment Core Samples

Density	Site	P ug/g	N %	Ca mg/g	K mg/g	Na mg/g	Mg mg/g	Mn mg/g	Aver. Redox	Redox Potential 0 cm	5 cm	10 cm	15 cm	20 cm
Low														
	C-7	530	1.8	390	14	8	9	N/A	138	254	124	94	94	124
	C-8	1600	1.18	230	16	5	4.5	8	59	164	-46	-6	39	144
	B-11	1750	1.69	168	32	8	6.5	9	176	259	184	124	129	184
	B-14	900	1.82	147	16	9	7	N/A	178	224	134	164	184	184
	B-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	B-2	220	.39	29	2	1	.7	47	95	124	104	84	44	119
	B-1	240	1.11	136	9	4	3.9	47	112	259	59	-6	124	124
	B-10	350	1.22	114	6	3	2	9	170	294	144	134	154	124
	B-5	360	1.76	144	14	19	4	N/A	181	284	124	149	164	184
	B-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	B-12	2540	2.19	180	31	8	6	N/A	174	264	154	164	144	144
	B-13	510	.24	26	3	1	1	N/A	171	284	144	139	144	144
	B-17	210	.16	18	2	2	.6	N/A	148	214	94	144	144	144
	O-20	N/A	N/A	N/A	N/A	N/A	N/A	N/A	188	234	164	194	174	174
	O-6	250	.33	48	4	2	5	9	141	264	99	104	119	119
	O-9	1240	2.36	175	9	12	1.4	14	124	244	264	44	34	34
	O-16	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	O-1	260	1.44	170	10	9	17	12	200	284	214	154	174	174
	O-2	790	2.15	137	25	9	10	N/A	147	324	114	94	89	114
	O-5	240	.33	42	8	3	2.9	N/A	141	309	64	104	114	114
	O-13	N/A	N/A	N/A	N/A	N/A	N/S	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	O-18	1880	2.69	84	16	5	9	N/A	154	264	124	114	124	144
	O-19	500	.22	34	4	2	2.5	N/A	166	284	134	114	124	174
	O-11CF	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Mean	798.3	1.282	126.2	12.28	6.111	5.167	19.38	150.7					
	St Dev	706.7	.8340	92.39	9.291	4.639	4.178	17.16	34.79					
Medium														
	B-4	690	2.13	240	15	11	7	14	100	224	59	64	69	84
	O-11BD	850	2.44	235	11	21	24	N/A	28	214	4	-26	-26	-26
	O-12	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	O-15	840	.21	260	3	2	16	2	132	294	114	84	84	84
	O-17	410	.54	35	4	2	3.3	5	136	234	114	94	124	114
	O-3	1980	2.54	170	21	15	11	27	119	264	69	74	84	104
	Mean	954	1.572	188	10.8	10.2	12.26	12	103					
	St Dev	600.4	1.109	91.96	7.563	8.289	8.083	11.22	44.22					
High														
	C-6	2400	2.54	350	28	11	11	11	136	304	64	94	94	124
	B-6	1250	2.29	170	17	5	5	9	120	84	124	114	114	164
	B-8	1560	1.82	190	31	7	6	8	193	264	244	164	169	124
	B-16	970	1.6	144	10	4	6	9	170	224	144	164	154	164
	B-20	1150	2.01	180	11	3	7	8	154	244	164	84	124	154
	B-15	640	1.53	142	15	6	6	N/A	168	164	124	184	184	184
	O-4	1490	2.78	198	22	8	14.5	23	81	129	74	64	69	69
	O-7	770	.34	27	4	3	2.2	10	N/A	N/A	N/A	N/A	N/A	N/A
	O-8	400	.48	49	7	2	4	7	82	64	84	94	84	84
	O-14	1380	2.95	260	15	10	16	26	180	224	174	164	169	169
	O-10	2410	2.34	131	30	13	11	39	128	249	69	94	114	114
	Mean	1311.	1.88	167.4	17.27	6.545	8.064	15	141.2					
	St Dev	648.9	.8558	89.32	9.339	3.616	4.425	10.73	38.99					

Pore Water

Density	Site	P	NO3	Ca	K	Na	Mg	DIC	pH	S	Mn	H2S	CH4	NH4	Fe	Cl
Low		ppm	ppb	ppm	ppm	ppm	ppm	ppm		ppm	ppm	ppm	ppm	ppm	ppm	ppm
	C-7	0	.0145	19	3.3	2.9	10	203.2	N/A	11.5	N/A					
	C-8	.4	.026	16	8	2.8	6.7	278.2	7.2	N/A	N/A					
	B-11	N/A	N/A	7	6.2	.8	4.9	190.9	7.1	10	N/A					
	B-14	0	.012	12	4.6	2.2	5.4	158.2	6.85	10	N/A					
	B-3	0	N/A	10	2.3	1.3	4	85.90	6.95	.01	N/A					
	B-2	0	N/A	8	1.4	1.3	3.3	87.26	6.95	9.4	N/A					
	B-1	0	.0115	9	3.3	1.8	3.5	79.08	6.95	6.8	N/A					
	B-10	0	N/A	10	3.3	1.5	4.1	201.8	6.9	14.9	N/A					
	B-5	N/A	N/A	8	2.8	1.7	3.3	133.6	6.9	14.5	N/A					
	B-7	0	N/A	8	3.3	1.7	4	57.27	7.75	.01	N/A					
	B-12	.03	N/A	11	2	1.8	5.1	N/A	N/S	N/A	N/A					
	B-13	.07	.0145	19	3.6	2.8	5.3	169.1	6.85	19	N/A					
	B-17	.01	.0115	10	2.2	1.9	3.9	137.7	7	N/A	N/A					
	B-3R	.16	N/A	103	3.9	2.7	4.4	91	7	N/A	.69	.668	8.63	14.57	.07	5.66
	B-16R	.19	N/A	52	3.6	3.1	4.2	12	6.63	N/A	1.1	.102	10.05	5.29	.432	5.34
	B-1R	.001	N/A	130	4.2	2.7	4.9	114	6.9	N/A	.7	.013	17	18.63	.843	5.07
	B-2R	.002	N/A	115	3.2	2.3	5.2	100	6.96	N/A	.36	.251	17.4	15.12	.053	4.86
	0-20	.387	.089	74	4.9	1.8	1.2	91.35	6.6	N/A	2.43					
	0-6	.005	.036	53	2.6	4	1	49.09	7.27	N/A	1.07					
	0-9	.047	.043	40	.9	1.8	.6	68.18	6.5	N/A	.55					
	0-16	.0075	.031	63	5	2.1	2.1	56.72	6.55	N/A	.8					
	0-1	.02	.032	54	2.6	1.2	1.1	92.17	6.8	N/A	1					
	0-2	.372	.061	55	3.4	.4	.9	72.54	7.1	N/A	.98					
	0-5	0	.027	47	2.1	.4	.8	37.09	7.45	N/A	.996					
	0-13	.054	.059	56	4.5	1.5	.9	76.36	6.65	N/A	1.29					
	0-18	.023	.02	54	2.7	3.1	1.5	35.18	6.55	N/A	.38					
	0-19	.074	.043	80	6	1.8	1.5	73.90	6.8	N/A	N/A					
	0-11CF	.0025	.073	48	6.4	1.7	.9	63.81	6.65	N/A	.82					
	Mean	.0742	.0355	41.82	3.654	1.968	3.382	104.3		9.612	.9404	.2585	13.27	13.40	.3495	5.233
	St dev	.1274	.0232	35.01	1.612	.8336	2.227	61.69		6.112	.5076	.2901	4.578	5.699	.3726	.3462
Medium																
	B-4	N/A	N/A	9	2.5	1.7	3.6	152.7	6.9	19	N/A					
	0-11BD	.0125	.038	45	4.6	1.7	.8	43.63	6.68	N/A	1.03					
	0-12	.23	.036	41	2.5	2.6	1	53.45	7.07	N/A	.5					
	0-15	.0025	.027	48	3.8	1.6	1.3	42.81	6.63	N/A	.88					
	0-17	.004	.023	54	3.1	2.3	1.1	36.81	6.6	N/A	.39					
	0-3	.105	.04	66	6.4	.6	1.1	101.7	7.05	N/A	1.17					
	Mean	.0708	.0328	43.83	3.817	1.75	1.483	71.86		19	.794					
	St dev	.0988	.0074	19.16	1.501	.6892	1.050	46.12			.3369					
High																
	C-6	.36	.026	16	5.1	2.7	7	245.4	N/A	23.5	N/A					
	B-6	N/A	N/A	7	1.5	.5	2.7	201.8	6.65	16	N/A					
	B-8	.17	N/A	12	2.5	1.1	3.8	201.8	N/A	33	N/A					
	B-16	0	N/A	7	2.3	1.3	3.5	125.4	6.75	14	N/A					
	B-20	0	N/A	10	2.2	1.3	4	196.3	6.85	23	N/A					
	B-15	0	N/A	10	3.2	1.6	4.2	163.6	7.15	16	N/A					
	B-0R	.2	N/A	81	5.2	2.9	5.1	82	6.78	N/A	2.4	.0545	11.45	6.16	1.52	4.93
	B-6R	.01	N/A	63	3.3	3.1	2.6	58	6.8	N/A	.37	.249	5.6	1.15	.15	5.68
	B-4AR	.001	N/A	55	2.2	2.4	3.4	48	6.96	N/A	.29	.063	8.18	2.6	.34	4.61
	B-4BR	.002	N/A	54	3.5	3.1	4	50	6.98	N/A	.38	.263	10.6	3.12	.27	4.74
	0-4	.05	.024	46	5.3	.4	.8	74.17	6.83	N/A	.83					
	0-7	.004	.013	38	1.7	.4	.6	33.54	7.3	N/A	1.22					
	0-8	0	.012	38	3.9	.4	.6	38.18	7.4	N/A	.72					
	0-14	.18	.054	65	5.4	2.5	1.1	76.90	6.8	N/A	.93					
	0-10	.005	.037	41	2.7	2.2	.7	49.90	6.43	N/A	.8					
	Mean	.0701	.0277	36.2	3.333	1.727	2.94	109.7		20.92	.8822	.1574	8.958	3.258	.57	4.99
	St dev	.1125	.0159	24.53	1.359	1.033	1.897	72.55		7.116	.6443	.1141	2.632	2.107	.6382	.4784

Shoots

Density	Site	p	Mg	Mn	Na	k	Ca
Low		mg/g	mg/g	mg/g	mg/g	mg/g	mg/g
	0-1	1.25	240	95	70	270	2500
	0-6A	1.038	220	126	160	490	1900
	0-6B	1.25	340	193	120	430	2100
	0-6C	1.125	210	93	30	230	2000
	0-9	1.225	210	167	90	330	2160
	0-20	.875	190	102	100	290	1800
	C-8C	1.325	260	52	340	570	16900
	B-1/2B	1.612	220	73	390	700	2400
	B-10B	1.175	180	50	280	670	6900
	B-11B	1.15	140	13	300	900	6600
	Mean	1.203	221	96.4	188	488	4526
	St dev	.1919	53.22	54.63	127.6	220.1	4759.
Medium							
	0-3	1.35	210	68	150	420	2000
	0-12	.875	180	132	20	280	4000
	0-15	.725	180	64	110	400	1440
	0-17	1	190	74	90	340	1700
	B-4B	1.425	200	215	400	110	2200
	Mean	1.075	192	110.6	154	310	2268
	St dev	.3026	13.04	64.58	145.4	124.5	1011.
High							
	0-4	1.412	200	68	110	590	1260
	0-7	1	200	77	160	470	1900
	0-8	1.125	180	107	150	540	1900
	0-10	1	190	169	80	420	2900
	0-14	1.125	190	79	70	260	2300
	C-6C	.75	260	54	230	410	20200
	B-6B	1.15	180	45	320	950	9690
	B-8B	1.317	170	38	290	500	7420
	B-16B	1	200	59	300	800	10100
	B-20B	1.112	200	36	270	630	12900
	Mean	1.112	197	73.2	198	557	7057
	St dev	.1899	24.52	40.19	95.71	197.2	6195.

Roots

Density	Site	P	Mg	Mn	Na	K	Ca
Low		mg/g	mg/g	mg/g	mg/g	mg/g	mg/g
	0-1	1.662	170	73	0	170	1500
	0-6A	.7	140	71	50	450	960
	0-6B	1.45	250	182	210	1000	1260
	0-6C	1.25	260	137	150	700	1430
	0-9	1.225	150	97	120	400	910
	0-20	1.125	200	161	50	320	1490
	C-8C	1.8	200	122	580	2100	13400
	B-1/2B	N/A	N/A	N/A	N/A	700	N/A
	B-10B	1.312	180	51	260	1100	1400
	B-11B	1.462	210	12	390	1800	1160
	Mean	1.332	195.6	100.7	201.1	974	2612
	St Dev	.3201	40.96	54.79	186.4	640.7	4051
Medium							
	0-3	1.25	190	72	100	520	1210
	0-12	1.4	180	50	90	430	1380
	0-15	.875	200	94	170	570	1100
	0-17	1.35	220	107	190	630	1030
	B-4B	1.325	240	90	330	1300	1500
	Mean	1.24	206	82.6	176	690	1244
	St Dev	.2111	24.08	22.11	96.33	348.5	194.8
High							
	0-4	N/A	N/A	N/A	N/A	N/A	N/A
	0-7	1.25	160	114	190	610	1070
	0-8	1.375	200	93	190	900	1540
	0-10	1.275	160	92	180	550	970
	0-14	1.325	210	108	270	800	1150
	C-6C	1.938	310	57	490	1100	11100
	B-6B	1.328	220	50	250	1100	2700
	B-8B	1.85	260	25	270	1200	2200
	B-16B	1	180	11	150	2100	1570
	B-20B	1.375	210	27	440	1800	1190
	Mean	1.414	212.2	64.67	254.4	1041	2606
	St Dev	.2956	48.43	39.24	110.9	365.8	3236

PORE WATER CHEMICAL COMPOSITION AT STATION 1 ON SEPTEMBER 11, 1981

	PH **	DIC MM	CH4 MM	PO4 UM	NH4 UM	CL UM	H2S UM
6-3-	8.57	1.53	0.01	0.04	.01	120.	0.01
3-0-	8.53	1.61	0.01	0.11	0.01	118.	0.01
0-3-	7.54	4.33	0.40	0.03	201.	135.	0.3
3-6-	7.07	6.53	0.94	0.04	559.	141.	0.1
6-9-	6.95	7.67	1.07	0.04	831.	143.	0.3
9-12-	6.85	9.51	1.22	0.05	1032.	147.	0.3
12-15-	6.78	9.80	1.22	0.05	1204.	149.	0.3
15-18-	6.80	11.23	1.23	0.05	1290.	149.	0.4
18-21-	6.77	11.49	1.22	0.04	1333.	149.	0.3
21-24-	6.74	11.09	1.05	0.05	1353.	147.	0.5
24-27-	6.74	11.10	1.13	0.03	1281.	120.	0.5
27-30-	6.74	11.87	1.13	0.03	1266.	149.	0.9
30-33-	6.70	11.57	1.08	0.11	1223.	153.	3.4
33-36-	6.71	11.11	1.06	0.76	1209.	153.	4.9
36-39-	6.80	11.20	1.02	0.47	1194.	151.	3.9
39-42-	6.75	11.34	1.05	0.18	1194.	151.	2.5
42-45-	6.81	11.79	1.03	0.19	1203.	155.	1.8
45-48-	6.70	11.73	1.07	0.83	1223.	157.	1.0

	CA MM	MG UM	FE UM	MN UM	NA UM	K UM
6-3-	0.96	132.	0.8		108.	6.0
3-0-	1.07	135.	3.0			5.4
0-3-	2.17	162.	10.2	8.4	103.	26.7
3-6-	2.71	184.	18.4	13.2	108.	54.3
6-9-	2.96	193.	17.6	13.6	119.	80.4
9-12-	3.16	195.	20.6	14.0	115.	99.6
12-15-	3.48	199.	20.9	15.0	116.	116.6
15-18-	3.56	217.	18.3	14.8	120.	134.7
18-21-	3.65	219.	13.8	13.9	120.	143.8
21-24-	3.73	223.	9.1	12.7	119.	149.4
24-27-						
27-30-	3.78	219.	7.0	9.9	125.	156.2
30-33-	3.70	212.	5.8	9.3	123.	156.2
33-36-	3.75	204.	5.2	8.9	120.	161.9
36-39-	3.78	212.	4.6	8.8	120.	164.1
39-42-	3.81	210.	7.3	8.5	118.	160.8
42-45-	3.72	197.	5.9	8.0	120.	159.6
45-48-	3.75	193.	8.3	7.9	120.	161.9

PORE/WATER CHEMICAL COMPOSITION AT STATION 2 ON SEPTEMBER 11, 1981

	PH **	DIC MM	CH4 MM	PO4 UM	NH4 UM	CL UM	H2S UM
9-6-	8.42	1.60	0.01	0.07	0.01	122.	0.01
6-3-	8.43	1.61	0.01	0.03	0.01	122.	0.01
3-0-	8.38	1.51	0.01	0.03	0.01	119.	0.01
0-3-	7.61	4.09	0.33	0.06	202.	127.	0.7
3-6-	7.19	5.57	0.85	0.05	491.	132.	6.4
6-9-	7.03	7.38	1.09	0.06	687.	136.	10.0
9-12-	6.95	7.53	1.15	0.07	810.	136.	11.7
12-15-	6.90	8.44	1.24	0.07	908.	136.	11.4
15-18-	6.86	9.22	1.28	0.05	994.	138.	8.6
18-21-	6.80	9.44	1.22	0.06	1053.	137.	7.9
21-24-	6.76	10.56	1.22	0.08	1084.	140.	6.3
24-27-	6.75	10.98	1.28	0.080	1096.	144.	5.8
27-30-	6.77	10.40	1.21	0.08	1072.	146.	5.0
30-33-	6.74	10.65	1.21	0.39	1047.	146.	9.3
33-36-	6.76	11.14	1.10	1.80	1041.	149.	10.0
36-39-	6.74	11.18	1.06	5.19	1035.	147.	8.2
39-42-	6.73	11.11	1.17	9.17	1041.	149.	6.4
42-45-	6.76	11.27	1.23	13.40	1053.		2.8

	CA MM	MG UM	FE UM	MN UM	NA UM	K UM
9-6-	0.89	122.	0.3	0.01	101.	5.9
6-3-	0.87	128.	0.3	0.01	97.	5.6
3-0-	0.89	126.	0.1	0.01	98.	5.2
0-3-	1.95	167.	1.3	4.8	98.	20.3
3-6-	2.44	186.	0.9	6.0	105.	40.6
6-9-	2.62	199.	0.5	6.4	102.	53.4
9-12-	2.73	205.	0.5	6.5	101.	64.1
12-15-	2.89	218.	0.9	6.8	101.	78.0
15-18-	2.78	218.	1.1	7.1	101.	89.7
18-21-	3.12	234.	1.0	7.5	100.	101.5
21-24-	3.27	238.	1.2	7.4	104.	119.7
24-27-	3.35	226.	1.1	7.3	103.	115.4
27-30-	3.47	228.		6.4	98.	123.9
30-33-	3.45	224.	1.1	5.7	100.	129.3
33-36-	3.42	201.		5.2	93.	132.5
36-39-	3.35	208.	1.1	4.6	93.	137.8
39-42-	3.42	205.		4.4	99.	143.2
42-45-	3.72	212.		4.6	116.	164.5

PORE WATER CHEMICAL COMPOSITION AT STATION 4A ON SEPTEMBER 11, 1981

	PH **	DIC MM	CH4 MM	PO4 UM	NH4 UM	CL UM	H2S UM
9-6-	8.52	1.38	0.01	0.04	0.01	114.	0.01
6-3-	8.49	1.43	0.01	0.03	0.01	114.	0.01
3-0-	8.47	1.34	0.01	0.03	0.01	112.	0.01
0-3-	8.02	1.88	0.06	0.07	26.	95.	0.01
3-6-	7.24	3.49	0.52	0.04	151.	130.	1.8
6-9-	7.08	3.75	0.66	0.05	179.	133.	5.2
9-12-	6.96	3.75	0.71	0.05	166.	130.	8.6
12-15-	6.87	3.81	0.71	0.05	159.	133.	10.4
15-18-	6.78	4.24	0.77	0.07	177.	147.	18.0
18-21-	6.71	4.67	0.85	0.05	202.	157.	19.4
21-24-	6.89	4.63	0.76	0.05	202.	141.	7.0
24-27-	6.65	5.41	0.77	0.05	225.	136.	3.8
27-30-	6.63	5.91	0.82	0.10	248.	135.	3.1
30-33-	6.61	5.98	0.83	0.49	274.	136.	3.2
33-36-	6.60	6.71	0.90	0.66	292.	133.	4.2
36-39-	6.65	6.74	0.90	1.27	310.	138.	3.6
39-42-	6.60	6.71	0.91	2.18	323.	133.	2.0
42-45-	6.61	6.77	0.89	3.68	330.	133.	1.8

	CA MM	MG UM	FE UM	MN UM	NA UM	K UM
9-6-	0.70	127.	0.5	0.01	114.01	20.0
6-3-	0.71	129.	0.3	0.01	114.01	20.3
3-0-	0.70	128.	0.3	0.01	112.01	19.5
0-3-	0.98	153.	1.5	0.01	95.01	21.0
3-6-	1.32	173.	5.8	12.4	130.01	37.6
6-9-	1.27	168.	5.6	9.8	133.01	46.5
9-12-	1.24	167.	3.8	7.9	130.01	45.4
12-15-	1.20	168.	4.5	8.5	133.01	52.0
15-18-	1.26	171.	3.9	7.6	147.01	87.5
18-21-	1.36	168.	4.4	6.5	157.01	104.1
21-24-	1.30	146.	4.8	5.1	141.01	77.5
24-27-	1.55	156.	6.8	6.0	136.01	81.9
27-30-	1.65	162.	7.3	5.7	135.01	83.0
30-33-	1.75	168.	7.5	6.4	136.01	95.2
33-36-	1.80	172.	7.9	7.0	133.01	94.1
36-39-	1.70	171.	6.6	6.6	138.01	99.6
39-42-	1.81	177.	7.5	6.5	133.01	96.3
42-45-	1.84	175.	4.8	5.5	133.01	99.6

PORE WATER CHEMICAL COMPOSITION AT STATION O ON SEPTEMBER 11, 1981

Depth cm	Eh mV	pH	CH_4 $mmol \cdot l^{-1}$	DIC $mmol \cdot l^{-1}$	H_2S $umol \cdot l^{-1}$	PO_4^{-3} $umol \cdot l^{-1}$	Cl^- $umol \cdot l^{-1}$	NH_4^+ $umol \cdot l^{-1}$	Ca $umol \cdot l^{-1}$	Mg $mmol \cdot l^{-1}$	Na $umol \cdot l^{-1}$	K $umol \cdot l^{-1}$	Fe $umol \cdot l^{-1}$	Mn $umol \cdot l^{-1}$
6- 3	-	8.48	0.00	1.57	0.0	0.07	123	0	0.72	130	121	23.1	0.5	0.0
3- 0	-	8.48	0.00	1.53	0.0	0.10	125	3	0.76	126	115	22.4	1.0	0.0
0- 3	-	7.28	0.36	3.19	3.9	6.9	135	106	1.37	150	123	37.9	5.7	29.1
3- 6	-	7.01	0.59	5.07	4.2	9.0	135	239	1.96	167	115	69.0	11.3	41.9
6- 9	-	6.86	0.53	6.04	1.6	2.4	135	269	2.11	188	115	103	15.7	48.1
9-12	-	6.77	0.47	6.48	1.0	0.96	135	281	1.99	194	127	127	26.5	50.9
12-15	-	6.71	0.54	7.07	0.9	1.9	142	316	1.92	196	125	150	43.1	49.8
15-18	-	6.74	0.67	7.54	0.7	4.6	138	382	2.05	218	127	166	43.1	45.3
18-21	-	6.63	0.91	8.20	0.9	8.6	144	432	2.08	224	124	168	42.0	48.7
21-24	-	6.60	0.97	8.14	1.3	10.1	146	459	2.20	241	120	168	33.1	44.7
24-27	-	6.61	1.05	8.15	1.0	10.7	140	467	1.33	252	135	169	29.4	41.9
27-30	-	6.60	1.06	8.68	1.5	10.6	140	470	2.28	254	128	166	22.8	38.6
30-33	-	6.63	1.10	8.65	1.0	10.3	133	462	2.22	248	126	164	19.8	33.6
33-36	-	6.62	1.05	8.74	1.8	9.3	129	457	2.27	259	132	163	18.7	33.0
36-39	-	6.62	1.10	8.96	1.5	8.5	129	451	2.30	265	120	157	16.1	29.6
39-42	-	6.60	1.10	8.94	1.7	9.1	125	457	2.43	269	127	154	19.4	28.0
42-45	-	6.57	1.16	9.29	2.9	13.8	123	483	2.57	274	146	158	23.9	28.5

PORE WATER CHEMICAL COMPOSITION AT STATION 3 ON SEPTEMBER 11, 1981

Depth cm	Eh mV	pH	CH_4 mmol•l^{-1}	DIC mmol•l^{-1}	H_2S umol•l^{-1}	PO_4^{-3} umol•l^{-1}	Cl^- umol•l^{-1}	F^- umol•l^{-1}	NH_4^+ umol•l^{-1}	Ca umol•l^{-1}	Mg mmol•l^{-1}	Na umol•l^{-1}	K umol•l^{-1}	Fe umol•l^{-1}	Mn umol•l^{-1}
6- 3	478	8.39	0.00	1.74	0.00	0.03	121	3.0	0	0.93	130	111	7.0	0.4	-
3- 0	476	8.15	0.00	1.65	0.00	0.04	121	3.0	0	0.95	125	105	5.7	0.4	1.9
0- 3	44	7.69	0.07	2.40	13.4	0.03	128	2.8	71	1.25	130	107	12.8	0.6	3.1
3- 6	-25	7.25	0.42	4.47	19.1	0.04	156	2.9	250	1.93	151	121	41.7	0.9	10.4
6- 9	-33	7.10	0.49	6.12	14.3	0.04	168	2.6	429	2.33	153	120	71.6	1.8	12.6
9-12	-32	6.99	0.35	6.92	14.0	0.09	172	2.7	554	2.59	175	119	109.0	-	12.8
12-15	-31	6.93	0.38	7.82	16.7	0.05	174	2.6	696	2.70	175	121	127.7	1.4	13.5
15-18	-32	6.86	0.49	8.83	19.2	0.06	177	-	768	2.90	184	115	136.7	-	14.6
18-21	-30	6.82	0.65	9.29	25.2	0.08	163	2.6	1036	2.97	195	122	146.4	1.5	14.7
21-24	-26	6.81	0.72	9.30	30.2	2.1	163	-	1234	3.07	195	119	120.7	-	14.9
24-27	-24	6.79	0.85	10.22	25.6	11.1	149	2.6	1448	3.08	217	103	116.4	1.3	15.0
27-30	-22	6.76	0.97	10.74	24.0	37.5	146	-	1609	2.90	221	109	112.2	-	14.4
30-33	-21	6.75	1.15	10.48	25.3	72.6	148	2.8	1841	2.93	228	126	106.8	1.2	13.4
33-36	-20	6.72	1.23	10.75	28.3	95.6	145	-	1859	2.72	241	137	107.9	-	15.1
36-39	-19	6.74	1.31	11.84	28.6	123.9	146	2.8	2199	2.95	271	141	112.2	1.9	14.4
39-42	-19	6.73	1.34	12.67	27.0	138.1	153	-	2253	2.82	263	140	125.0	-	11.7
42-45	-	6.63	1.32	12.88	28.1	145.1	153	2.9	2253	3.14	296	143	143.2	1.5	11.2
45-48	-	6.60	1.27	13.16	27.9	182.3	155	-	2592	3.06	296	150	143.2	-	10.7

PORE WATER CHEMICAL COMPARISON AT STATION 18 (pelagic) ON SEPTEMBER 11, 1981

Depth cm	Eh mV	pH	CH_4 mmol·l^{-1}	DIC umol·l^{-1}	H_2S umol·l^{-1}	PO_4^{-3} umol·l^{-1}	Cl^- umol·l^{-1}	NH_4^+ umol·l^{-1}	Ca mmol·l^{-1}	Mg umol·l^{-1}	Na umol·l^{-1}	K umol·l^{-1}	Fe umol·l^{-1}	Mn umol·l^{-1}
6– 3	501	8.36	0.00	1.51	0.0	0.03	124	0	0.80	140	129	22.9	0.0	-
3– 0	500	8.39	0.00	1.46	0.0	0.03	124	0	0.79	142	126	23.3	0.5	-
0– 3	352	8.01	0.00	1.50	0.2	0.2	128	4	0.82	140	117	22.2	15.8	-
3– 6	41	7.50	0.31	2.86	0.1	8.6	136	133	1.27	172	126	29.9	66.8	43.1
6– 9	25	7.26	0.75	3.76	0.3	22.8	145	271	1.38	203	133	38.8	143	68.4
9–12	27	7.17	0.95	3.94	0.2	32.3	149	335	1.45	211	139	46.5	173	69.0
12–15	33	7.14	0.99	4.28	0.1	40.5	149	355	1.46	209	133	49.9	170	58.6
15–18	30	7.13	0.97	3.85	0.1	42.1	145	347	1.46	213	141	48.7	148	47.7
18–21	27	7.11	0.88	3.83	0.1	40.3	149	333	1.37	220	139	48.7	125	40.2
21–24	26	7.12	0.75	3.81	0.1	34.0	140	299	1.42	220	144	47.6	108	36.8
24–27	28	7.16	0.71	3.64	0.2	24.5	145	271	1.33	216	144	46.5	86	29.3
27–30	29	7.17	0.63	3.53	0.2	15.4	143	240	1.26	211	138	43.2	58	23.0
30–33	31	7.19	0.54	3.35	0.1	10.9	140	218	1.29	216	137	43.2	47	19.5
33–36	35	7.17	0.49	3.15	0.2	9.9	138	200	1.29	216	142	38.8	46	18.4
36–39	36	7.11	0.45	3.35	0.2	10.6	140	192	1.24	211	139	39.9	50	15.5
39–42	-	7.16	0.39	3.24	0.3	13.6	145	186	1.23	216	144	38.8	54	16.7
42–45	-	7.17	0.36	3.22	0.3	15.9	140	185	1.24	220	143	39.9	60	16.1

PORE WATER CHEMICAL COMPARISON AT STATION 6A ON SEPTEMBER 11, 1981

Depth cm	Eh mV	pH	CH_4 $mmol \cdot l^{-1}$	DIC $umol \cdot l^{-1}$	H_2S $umol \cdot l^{-1}$	PO_4^{-3} $umol \cdot l^{-1}$	Cl^- $umol \cdot l^{-1}$	NH_4^+ $umol \cdot l^{-1}$	Ca $mmol \cdot l^{-1}$	Mg $umol \cdot l^{-1}$	Na $umol \cdot l^{-1}$	K $umol \cdot l^{-1}$	Fe $umol \cdot l^{-1}$	Mn $umol \cdot l^{-1}$
6- 3	467	7.81	0.00	2.14	0.0	0.03	153	0	1.01	136	137	21.5	0.7	-
3- 0	469	7.67	0.05	2.67	1.1	0.05	159	15	1.30	142	137	24.6	2.6	5.8
0- 3	154	7.16	0.35	4.09	4.5	0.05	159	97	1.53	177	131	48.1	4.1	11.9
3- 6	139	6.86	0.30	4.19	10.3	0.05	151	100	1.36	184	128	65	3.6	9.5
6- 9	162	6.75	0.22	4.50	7.1	0.11	151	69	1.38	179	128	75	3.8	9.4
9-12	166	6.77	0.30	4.69	8.9	0.16	151	61	1.49	177	133	85	2.9	8.3
12-15	165	6.75	0.33	4.66	7.0	0.35	157	51	1.44	171	142	91	2.2	6.3
15-18	164	6.74	0.38	4.86	5.6	0.59	160	46	1.61	189	140	94	2.1	-
18-21	166	6.73	0.37	5.14	8.3	0.77	165	44	1.62	200	137	98	-	4.4
21-24	168	6.74	0.37	5.36	7.4	0.31	168	46	1.71	201	136	95	1.6	3.9
24-27	169	6.78	0.43	5.43	6.9	0.14	168	54	1.83	208	136	92	1.8	3.6
27-30	169	6.75	0.45	5.44	6.8	0.34	171	72	1.86	210	146	94	2.1	3.5
30-33	167	6.79	0.56	6.04	7.0	0.18	175	84	1.86	213	147	86	2.2	3.3
33-36	167	6.74	0.56	5.95	6.3	0.26	168	100	1.90	210	144	84	2.5	3.0
36-39	-	6.81	0.62	6.02	4.9	0.81	168	113	1.99	213	139	79	2.5	2.7
39-42	-	6.75	0.70	6.47	4.4	1.11	169	123	2.02	217	140	76	2.3	2.7

PORE WATER CHEMICAL COMPARISON AT STATION 16 ON SEPTEMBER 11, 1981

Depth cm	Eh mV	pH	CH_4 mmol·l^{-1}	DIC umol·l^{-1}	H_2S umol·l^{-1}	PO_4^{-3} umol·l^{-1}	Cl^- umol·l^{-1}	NH_4^+ umol·l^{-1}	Ca mmol·l^{-1}	Mg umol·l^{-1}	Na umol·l^{-1}	K umol·l^{-1}	Fe umol·l^{-1}	Mn umol·l^{-1}
6- 3	492	8.08	0.00	1.46	0.0	0.03	128	0.0	0.79	137	121	22.4	0.2	-
3- 0	492	8.28	0.00	1.43	0.0	0.03	124	0.0	0.79	130	131	24.7	0.2	5.9
0- 3	32	7.22	0.35	2.90	1.6	3.4	152	93	1.32	154	151	50	4.8	21.9
3- 6	0	6.86	0.66	3.83	6.5	6.5	185	177	1.37	171	165	76	5.1	22.4
6- 9	6	6.71	0.62	3.47	6.9	5.7	177	162	1.15	158	154	73	5.1	17.6
9-12	14	6.66	0.55	3.45	5.0	5.1	148	156	1.02	150	131	62	4.8	18.2
12-15	16	6.60	0.49	3.43	3.9	4.0	152	179	1.05	147	125	65	5.1	17.1
15-18	20	6.52	0.58	3.95	1.7	3.4	152	234	1.19	171	132	82	5.9	16.6
18-21	22	6.49	0.71	5.21	1.5	4.9	140	328	1.30	171	128	105	7.1	18.7
21-24	22	6.45	0.77	5.68	0.8	6.4	140	432	1.45	186	128	125	9.0	21.9
24-27	22	6.43	0.92	6.30	1.0	9.1	132	541	1.59	209	124	143	14.3	21.9
27-30	22	6.40	-	-	1.1	11.4	128	637	1.58	192	125	147	16.2	23.5
30-33	22	6.40	1.02	7.31	1.0	14.0	119	713	1.73	222	124	153	19.2	25.6
33-36	23	6.41	1.06	7.88	0.9	16.3	115	785	1.79	222	123	154	14.3	25.1
36-39	23	6.39	1.06	8.26	2.3	20.2	124	868	1.83	244	122	154	13.5	26.2
39-42	-	6.40	1.01	8.12	1.4	24.6	132	929	1.85	244	116	156	13.5	24.6
42-45	-	6.40	1.07	8.56	2.6	30.9	124	998	1.96	237	120	170	13.3	26.2

Appendix 3: Observations and data from vermiculite, sawdust and charcoal experiment

Treatment	n	0	9	15	21	31	Growth Rate (cm/d)	P value	Density (g/ml)	Density % change	% Organic Content	Org Cont % change
		Average Shoot Lengths (cm) Days										
Control	7	6.5	18.4	34.4	42.1	103.9	3.1		.11165		35.6	
Vermiculite	6	6.0	16.3	29.3	39.8	61.7	1.8	0.015	.10406	-1.7	35.0	-1.7
2 cm sawdust layer	6	10.1	20.3	32.3	32.3	65.3	1.8	0.015				
sawdust mixed in	7	6.1	11.7	17.1	20.7	24.6	0.6	0.001	.11388	+4.5	37.2	+4.5

Treatment	n	0	54	69	Rate (cm/d)	DOC (mg/l)	DIC (mg/l)
		Days					
"Bad" sediment with charcoal	29	10	-	54.3	.64	0.5	12.6
"Bad" sediment without charcoal	26	10	-	53.3	.63	1.4	11.4
"Good" sediment with sawdust	9	10	26.5	-	.30	1.4	13.2
"Good" sediment without sawdust	15	10	52.3	-	.78	1.4	9.6

Appendix 4: Observations and data from insect grazing survey

Appendix 4

Lake	Site	Insect Damage	Med.	Moth Larvae	Moth Cases	Weevil Larvae
Scugog	1	0,0,1,0,4	0	0,0,2,0,0	0,0,0,0,0	0,0,0,0,0
	2	6,5,6,4,5	5	0,3,0,1,0	5,3,0,0,0	1,0,0,0,0
	3	-,4,4,0,4	4	-,0,1,1,1	-,0,0,1,2	-,0,0,0,0
	4	6,2,7,5,6	6	0,0,0,0,0	1,2,0,0,1	0,0,0,0,0
	5	1,6,6,5,5	5	0,0,0,0,0	1,0,0,0,5	0,0,0,0,0
Lake wide:			5	9	21	1
Chemung	1	6,5,5,5,4	5	0,0,1,0,0	0,0,1,0,0	0,0,0,0,0
	2	4,4,4,4,5	4	0,0,0,1,0	0,2,0,2,0	0,0,0,0,0
	3	6,4,5,4,5	5	0,2,2,0,0	0,2,0,0,1	0,1,0,0,0
	4	4,4,4,4,4	4	2,1,2,0,2	1,1,2,1,2	1,1,0,0,0
	5	5,2,4,4,1	3	2,0,0,0,0	2,0,0,1,0	0,0,0,0,1
Lake wide:			4	15	18	4
Buckhorn	1	1,4,0,1,1	1	1,1,0,1,0	0,1,0,1,0	0,0,0,0,0
	2	7,5,7,7,6	7	1,0,4,3,3	1,0,1,2,9	0,0,0,0,0
	3	4,5,5,6,4	5	0,1,2,0,1	0,1,6,0,2	2,0,0,0,1
	4	6,5,5,6,5	5	1,3,6,1,0	3,1,4,2,0	0,0,0,0,0
	5	4,0,3,5,1	3	0,1,1,2,2	0,2,3,4,4	0,0,0,0,0
Lake wide:			5	35	47	3
Pigeon	1	0,4,0,0,0	0	0,0,0,0,0	0,0,0,0,0	0,0,0,0,0
	2	4,2,2,0,4	2	1,1,0,0,0	0,3,0,0,1	0,0,0,0,0
	3	1,1,1,4,1	1	1,0,1,0,0	1,0,0,1,0	0,0,0,0,0
	4	3,4,4,4,4	4	0,0,0,1,0	2,0,3,1,0	0,0,0,0,0
	5	2,5,5,4,4	4	0,2,2,0,1	3,9,8,20,10	0,0,0,0,0
Lake wide:			4	10	62	0
Sturgeon	1	4,4,4,3,5	4	2,0,4,7,0	8,1,4,8,8	0,0,0,0,0
	3	4,5,0,1,0	1	1,2,0,0,0	1,0,0,2,1	0,0,0,0,0
	4	4,1,5,4,5	4	1,1,1,1,0	2,1,2,1,0	0,0,0,0,0
	5	5,2,2,1,4	2	3,0,1,0,0	8,0,0,0,0	0,0,1,1,0
Lake wide:			4	24	47	2
Lower Buckhorn	1	4,5,5,4,5	5	0,0,0,1,0	0,0,0,0,0	0,0,0,0,0
	3	4,4,5,4,4	4	2,0,1,1,1	7,0,1,0,0	0,0,0,0,0
	4	4,4,4,4,4	4	0,0,1,0,0	1,0,0,0,0	0,1,0,0,0
	5	1,4,4,3,4	4	2,0,0,2,0	1,0,0,0,0	0,0,0,0,0
Lake wide:			4	11	10	1
Newboro	1	4,4,4,4,4	4	0,0,0,0,1	0,0,0,0,0	0,0,0,0,0
	2	1,2,4,0,0	1	0,0,0,0,0	0,0,0,0,0	0,1,0,0,0
	3	4,5,1,5,1	3	0,0,2,0,0	0,0,0,0,0	0,0,0,0,0
	4	1,2,4,1,1	1	0,0,0,0,0	0,0,0,0,0	0,0,0,0,0
Lake wide:			3	3	0	1

Lake	Site	Insect Damage	Med.	Moth Larvae	Moth Cases	Weevil Larvae
Clear	1	4,3,0,1,3	3	0,0,0,0,0	0,0,0,0,0	0,0,0,0,0
Lake wide:			3			
Indian	2	4,1,4,4,4	4	0,0,0,0,0	0,0,0,0,0	0,0,0,0,0
	3	5,2,4,4,4	4	0,0,0,0,3	0,1,0,0,0	0,0,0,0,0
Lake wide:			4	3	1	0
Rice	1	4,5,5,4,4	4	2,1,0,0,0	3,0,2,0,0	0,2,0,0,0
	2	4,4,4,4,1	4	0,0,1,0,0	0,0,0,0,0	0,0,1,0,0
	3	5,4,4,5,5	5	1,0,0,0,0	0,0,1,2,1	2,0,1,0,1
	4	5,5,5,5,3	5	0,0,1,0,0	3,0,0,0,5	0,0,1,0,0
Lake wide:			4	6	17	8
Upper Rideau	1	1,2,0,2,1	1	0,0,0,0,0	0,0,0,0,0	0,0,0,0,0
	2	1,4,0,4,1	1	0,1,0,0,0	0,0,0,0,0	0,2,0,1,0
	3	5,0,5,5,3	5	0,0,0,0,0	0,0,0,0,0	2,0,0,0,1
	4	1,4,4,5,4	4	0,1,1,0,0	0,0,0,0,0	0,0,0,0,1
	5	2,4,4,2,1	2	0,0,0,0,0	0,0,0,0,0	0,0,0,0,0
Lake wide:			2	3	0	7
Lower Rideau	1	5,4,4,4,4	4	0,0,0,0,0	0,0,0,0,0	0,1,1,0,0
	2	4,4,4,4,4	4	0,0,0,0,0	0,0,0,0,0	0,1,0,0,1
	3	5,4,4,4,4	4	0,0,0,0,0	0,0,0,0,0	1,0,0,2,0
	4	0,4,4,4,4	4	0,0,0,0,0	0,0,0,1,0	0,4,0,1,0
	5	0,0,3,0,4	0	0,0,0,0,0	0,0,0,0,1	0,0,1,0,0
	6	1,1	1	0,0	0,0	0,0
Lake wide:			4	0	2	13
Katch	1	4,1,4,3,4	4	2,1,1,1,1	4,3,1,3,1	0,0,2,1,0
	2	4,3,4,4,3	4	2,0,1,0,0	3,0,1,0,1	0,1,1,3,0
Lake wide:			4	9	17	8
Stony	1	3,4,3,4,4	4	0,0,0,0,0	0,1,0,0,1	0,0,0,1,1
	2	0,0,4,4,0	1	0,0,0,0,0	0,0,0,0,0	0,0,0,0,0
Lake wide:			3	0	2	2
Opinicon	1	4,4,0,4	4	0,0,0,0	1,0,0,0	0,0,1,0
	2	2,2,2,2,1	2	0,0,0,0,0	0,0,0,0,0	0,0,0,0,0
	3	1,1,1,0,1	1	0,0,0,0,0	0,1,1,0,0	0,0,0,0,0
	4	2,1,1,4,2	2	0,0,0,0,0	0,0,0,0,0	0,0,0,0,0
Lake wide:			2	0	3	1

TRENT AND RIDEAU RIVER SYSTEMS

MILFOIL STATIONS

1986

LAKE	STATION NUMBER	ABUNDANCE	HEALTHY	LOCATION
Buckhorn	1	Light	Yes	Harrington Bay
	2	Light	No	Nicholls Pt.
	3	Moderate	No	Hall Pt.
	4	Light	No	North of Hall Pt.
	5	Light	Yes	South of lock
Chemong	1	Light	No	North of Birch I.
	2	Light	No	Curve Lake
	3	Light	Yes	Hickson Pt.
	4	Light	Yes	Lancaster Bay
	5	Heavy	Yes	(little creek)
Pigeon	1	Sparse	Yes	Bald Lake Narrows
	2	Sparse	Yes	Black Pt.
	3	Sparse	Yes	Back Channel
	4	Sparse	No	Blind Channel
	5	Sparse	No	Grassy Marsh
Scugog	1	Light/Moderate	Yes	Highland Beach
	2	Light	No	North of Nonquon R.
	3	Light	No	Gillson's Pt. - Newman's Beach
	4	Light	No	Bay East of Caesarea Marina
	5	Light	No	Alfred's Beach
Sturgeon	1	Moderate	Yes	Mouth of Emily Creek
	2	Nil	-	Verulam Park
	3	Light/Moderate	Yes	"Southview Estates"
	4	Sparse	No	Mile 150-151
	5	Light	No	Ellery Bay
Katchewanooka	1	Nil	-	Polly I.
	2	Nil	-	East of Hills I.
	3	Nil	-	West of Hills I.
	4	Light	No	West End
	5	Light	No	NE end of Third I.

LAKE	STATION NUMBER	ABUNDANCE	HEALTHY	LOCATION
Stony	1	Nil	-	Around Hurricane Pt.
	2	Moderate	No	South of Stubbs I.
	3	Light	Yes	West of Mount Julian
	4	Nil	-	Hamilton Bay
	5	Nil	-	Bryson's Bay
Lower Buckhorn	1	Light/Moderate	No	Marsh near Oak I.
	2	Nil	-	NW of Three Is.
	3	Light/Moderate	No	East of Three Is.
	4	Light	No	Jacknife I.
	5	Light/Moderate	No	North of Rose I.
Opinicon	1	Light	Yes	North of island North of Rabbit I.
	2	Moderate	No	Near cable ferry
	3	Heavy	Yes	Outside of Darling Bay
	4	Light	Yes	Deadlock Bay
	5	Nil	-	Eightacre I.
Newboro	1	Light	No	At The Bog
	2	Light	Yes	North of Scott I.
	3	Light/Moderate	Yes	Wright I.
	4	Light	Yes	Rosal Bay
	5	Nil	-	Islands SE of Sturgeon I.
Clear/Indian	1	Light	No	Before Marsh, West of Elbow Channel
	2	Light/Moderate	Yes	Island West of Dunn Pt.
	3	Light	No	Benson Pt.
	4	Nil	No	SE end of Lake
	5	Nil	-	Fish Sanctuary Bay
Rice	1	Moderate	No	West End
	2	Light	Yes	Jubilee Pt.
	3	Light	No	Sager Pt.
	4	Light	No	West of Sugar I.
	5	Nil	-	East End
Lower Rideau	1	Light	No	South of Frost Pt.
	2	Moderate	No	West of Stuarts Pt.
	3	Moderate	No	Beveridge Bay
	4	Light	No	Stonehouse I.
	5	Light	Yes	Briggs I.

LAKE	STATION NUMBER	ABUNDANCE	HEALTHY	LOCATION
Big Rideau	1	Light	Yes	Narrows Bay
	2	Sparse	?	Hudson Bay
	3	Nil	-	South of Turnip I.
	4	Nil	-	Davidsons Bay
	5	Light	Yes	Sunken I. - Peerless Shoal
Upper Rideau	1	Light	No	McNally's Bay, near Adrains Creek
	2	Light	No	Pipers Bay
	3	Nil	-	Big I.
	4	Moderate	Yes	Mooneys Bay
	5	Light/Moderate	Yes	Kanes Bay