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Environmental Effects Of Mechanical Harvesting

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ABSTRACT

Following 2 years of preliminary studies, an experimental aquatic plant harvesting program was initiated in southern Chemung Lake in 1973. Harvesting operations in 1975 resulted in the removal of 3.0 x 10^6 kg of plant material containing 560 kg of phosphorus. This value was equivalent to 47% of the gross and 92% of the net annual phosphorus loading to southern Chemung Lake. Reductions in algal biomass at station 4 in southern Chemung coincided with the harvesting program. Less pronounced decreases in algal biomass were observed at the remaining sampling stations. Peak biomass values of aquatic macrophytes ranged between 300 and 400 g dry weight per m^2. During the study period, Eurasian watermilfoil [*Myriophyllum spicatum* L.] increased in abundance with concurrent reductions in Northern watermilfoil [*Myriophyllum exalbescens* Fernald] and Vallisneria [*Vallisneria americana* Michx.]. In experimental plots, multiple harvests effectively reduced stem densities of Eurasian watermilfoil. Slight increases in stem numbers were noted in single harvest plots, although changes were minor compared to increases in the unharvested control plots. With the exception of yellow perch, fish populations remained stable throughout the study period. Decreases in perch populations were apparent both in northern and southern Chemung, thus eliminating harvester activity as a causative factor.

INTRODUCTION

Many of the major recreational lakes of southern Ontario are plagued by excessive growths of aquatic plants, particularly Eurasian watermilfoil. In the past, control of the nuisance vegetation has generally been accomplished by chemical means. Mechanical removal was thought to offer an alternative method which would have less damaging environmental consequences, particularly where fisheries was a major consideration.

In 1973, following 2 years of preliminary studies, the Ontario Ministry of the Environment initiated an experimental program for the purpose of assessing the effects of extensive vegetation removal on water quality, phytoplankton and macrophyte dynamics, and on lake fisheries. In addition, efforts were made to evaluate the efficiency of the mechanical systems employed and to investigate potential uses for the harvested vegetation.

DESCRIPTION OF THE STUDY AREA

Chemung Lake, located approximately 5 km northwest of the city of Peterborough, forms part of the Kawartha-Trent waterway (Figure 1). The lake is 24 km in length and has an average width of 1.3 km. The shoreline is heavily developed with cottages, permanent homes and numerous resorts. The lake is physically divided into two sections by a causeway with a narrow bridge near the east side. The

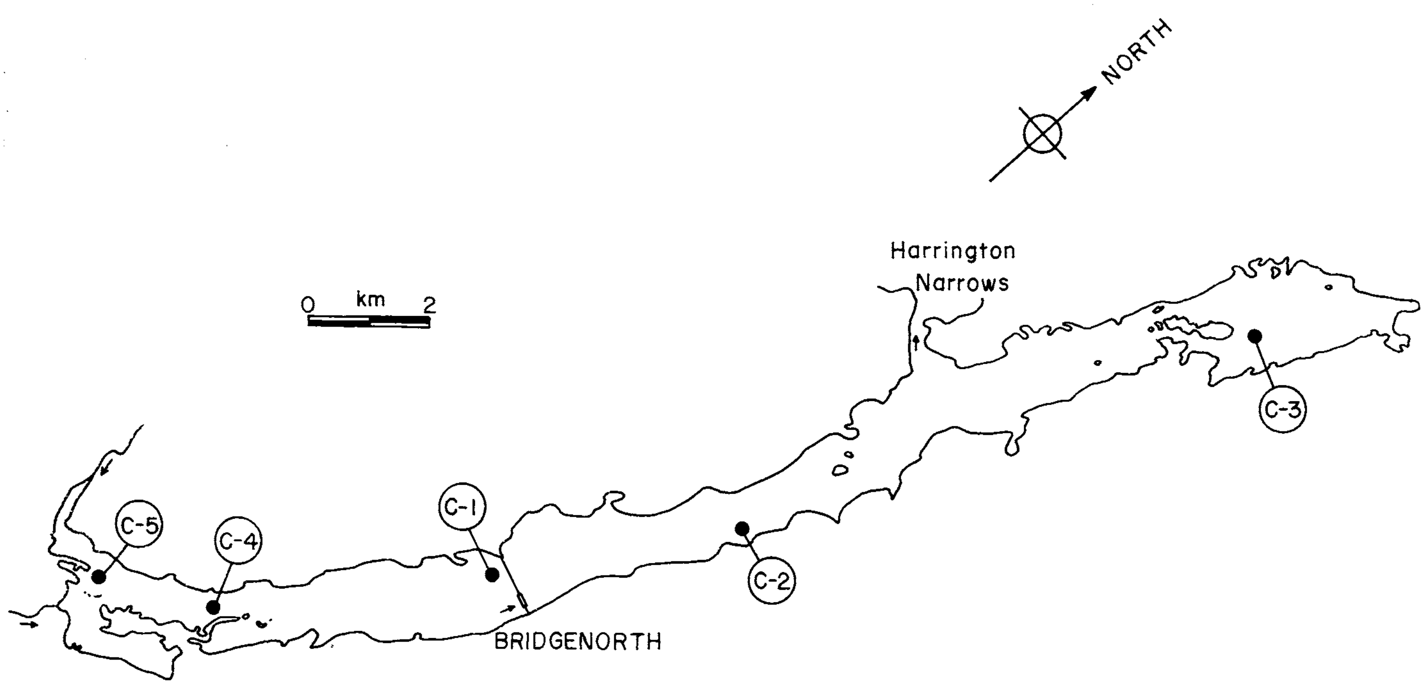

Figure. 1. Map of Chemung Lake showing inflowing streams, outflow at causeway and locations of sampling stations.

portion of the lake south of the causeway was selected as the study site for the experimental harvesting operation and the northern sector was used as a control area. The morphometric features of both northern and southern Chemung Lake are summarized in Table 1.

METHOD

Sampling was completed at weekly intervals during the ice-free periods at four stations in Chemung Lake. Control stations 2 and 3 were located in the northern portion of the lake at depths of 4.0 and 6.5 m. The remaining two stations were located in southern Chemung Lake, station 1 near the causeway in 6 m of water and station 4 in the shallow, weeded section of the lake (Figure 1).

Samples for water quality parameters, chlorophyll analysis and phytoplankton enumerations were secured as composites through the euphotic zone. All analyses were performed using standard laboratory techniques (13). Nutrient loading data were obtained from two gauged tributary streams and a rainfall collector located at Trent University in Peterborough. Information on the distribution of aquatic macrophytes was obtained by remote sensing techniques using conventional negative colour film. Species composition and biomass data were based on 0.25 m^2 quadrat samples collected at weekly intervals from forty sampling sites.

Changes in fish populations were monitored by the Ministry of Natural Resources using trap netting, tagging and recovery techniques as well as creel census data.

RESULTS AND DISCUSSION

Harvesting of aquatic vegetation was restricted to southern Chemung Lake between 1973 and 1975 as part of the experimental program. In 1976 the program was expanded as a public service to include other lakes in the immediate vicinity and as a result only a minor effort was expended in southern Chemung Lake. During 1973, harvesting operations resulted in the removal of 1290 metric tons of vegetation from an area of 266 ha. In 1974 and 1975, 2160 and 3380 metric tons of vegetation were removed from 262 and 297 ha, respectively.

Nutrient budget

Annual phosphorus loading to southern Chemung Lake was monitored in 1975 and compared to the quantity of phosphorus removed from the lake via the harvesting program (Table 2). The calculations ignored the potential input of phosphorus from the lake's sediments, a source found to be significant in some other shallow lakes (10). However, even in extremely eutrophic Lake Norrviken, the role of sediments as a nutrient source gradually declined once external inputs and the total phosphorus content of the lake were reduced (1).

Table 1. Morphometric data for Chemung Lake.

Parameter	Northern Chemung Lake	Southern Chemung Lake
Area (ha)	1646	858
Maximum depth (m)	6.7	6.1
Mean depth (m)	2.1	1.8
Volume (m^3)	3.40×10^7	1.58×10^7

Table 2. Summary of phosphorus inputs and phosphorus losses for southern Chemung Lake.

		P (kg)	%
INPUTS			
land drainage		500	42
precipitation		490	41
artificial		200	17
	Total	1190	
OUTPUTS			
outflow		580	49
RETENTION			
S_{net}		610	51
P REMOVAL			
plant harvesting		560	
fish export		30	

Overland drainage and precipitation were the major contributors of phosphorus to the lake, accounting for 83% of the annual input. Land drainage estimates were based on data collected from Lancaster and Chemung Creeks which drain two separate basins of the lower Chemung Lake watershed. The third catchment was not drained by permanent streams and as a result could not be instrumented. Inputs from this basin were derived by assuming that the total water equivalent of winter precipitation would reach the lake since the ground was either frozen or saturated. A factor of 19.4% of the precipitation was used for the balance of the season, based on information obtained from the two gauged basins.

Artificial inputs represented 17% of the annual phosphorus loading and were derived from the following equation:

$$J_A = 0.80 \text{ kg P/capita year} \times \text{number of residences} \times \text{average number of capita years/residence.}$$

The value of 0.8 kg per capita year was based on Dillon and Rigler (5) and the occupancy rates were determined by a field survey of the residences adjacent to the lake. Since studies of septic tank disposal systems on Chemung Lake showed high phosphorus retention in the tile fields (2), a retention factor of 80% was used to derive the final loading figure of 200 kg P per year for artificial inputs.

Phosphorus losses (O_T) from the lake via the outflow were equivalent to 49% of the input and were derived from the following equations:

$$\text{Outflow volume (Q)} = \text{Precipitation on lake (Pr)} + \text{Runoff (R)} - \text{Evaporation (Ev)}$$

$$O_T = Q \times \text{P concentration in outflow}$$

The annual net phosphorus retention was calculated as the difference between the various inputs and P losses via the outflow and represented 51% of the total annual P input to the lake.

Harvesting operations in 1975, removed 3.0×10^6 kg of plant material which contained a total of 560 kg of phosphorus. This value is equivalent to 47% of the gross annual loading and 92% of the net P retained in the lake.

In a similar study conducted in Lake Sallie, Minnesota (14), aquatic plant harvesting operations removed only 1.4% of the total phosphorus loadings to the lake, leading the authors to conclude that harvesting was not effective as a method of reducing nutrient supplies in lakes receiving cultural enrichment. When data for the two lakes are compared, the reasons for the discrepancy in conclusions are readily apparent. Harvesting operations in Lake Sallie removed only 4.28 x 10^5 kg of plant material or less than one sixth of the quantity removed from southern Chemung Lake. Since Lake Sallie is a deeper body of water (mean depth 5.6 m) the macrophytes cover only 158 ha of the total area of the lake, compared to 435 ha in southern Chemung. In addition, Lake Sallie has a 60-year history of nutrient enrichment by wastewater effluent, with an annual phosphorus input of 7285 kg compared to an input of only 1190 kg in southern Chemung Lake. From the foregoing, it is apparent that harvesting of aquatic vegetation cannot be expected to contribute significantly to nutrient reduction in Lake Sallie.

Water Quality

Temperature differences between surface and bottom strata were generally less than 1 C in Chemung Lake throughout the study period. Surface dissolved oxygen concentrations rarely fell below 80% saturation and changes with depth were minimal.

Mean values for nitrogen and phosphorus are presented in Table 3. Mid-summer nitrate-nitrogen depletion and high organic nitrogen values are characteristic of highly productive environments. Seasonal mean values for phosphorus show a progressive increase from northern to southern Chemung Lake, both prior to and following commencement of harvesting operations. Hutchinson (1957) indicated that phosphorus may limit production in lakes where the N/P ratio is high, whereas nitrogen would be expected to limit production where the ratio is less than 8:1 (by weight). The high N/P ratios in Chemung Lake suggest that phosphorus may be the key factor controlling production and therefore continuous P removal via harvesting represents a potential means of reducing productivity. Although nutrient budget data for 1975 indicate that 47% of the gross and 92% of the net annual P loading to southern Chemung Lake was removed via harvesting, significant reductions in ambient P concentrations were not apparent. Since aquatic plants are generally believed to obtain their phosphorus both from the water and sediment, (3, 4) it is likely that harvesting would have to be continued over an extended period of time before significant reductions in P levels could be achieved.

Phytoplankton

Many workers have reported on the antagonistic relationship between aquatic macrophytes and phytoplankton (8, 6). In lakes where phytoplankton production is inhibited by secretion of substances produced by the macrophytes or by competition for nutrients, removal of the vegetation could potentially result in increased algal production. This appeared to be the case in Lake Sallie, where elevated algal densities were noted after the first year of harvesting operations (11). In Chemung Lake increases in algal biomass were not observed following commencement of the harvesting program. A maximum biomass of 4700 aerial standard units per ml (a.s.u./ml) was obtained at station 4 in the preharvest period followed by a gradual decline to 1700

TABLE 3. MEAN NITROGEN AND PHOSPHORUS CONCENTRATIONS IN THE EUPHOTIC ZONE OF CHEMUNG LAKE EXPRESSED IN μg PER LITER.

Station	Parameter	1971	1972	1973	1974	1975	1976
North							
C-2	Total P	23	23	18	27	19	19
	NH_3-N	<10	60	50	40	60	30
	*TK-N	510	550	510	620	590	560
	NO_2-N	3	4	2	2	2	3
	NO_3-N	30	40	10	20	20	30
C-3	Total P	26	21	16	20		
	NH_3-N	20	40	50	50		
	TK-N	550	580	480	590		
	NO_2-N	3	3	2	2		
	NO_3-N	30	30	20	30		
South							
C-1	Total P	27	24	24	31	23	23
	NH_3-N	20	30	50	30	70	50
	TK-N	530	550	560	640	600	590
	NO_2-N	3	4	2	3	3	3
	NO_3-N	40	40	20	30	30	50
C-4	Total P	32	30	26	33	23	23
	NH_3-N	30	30	70	40	50	40
	TK-N	600	620	630	720	620	560
	NO_2-N	3	4	2	3	3	3
	NO_3-N	20	30	20	30	30	20

*TK-N—Total Kjeldahl Nitrogen

aerial standard units per ml by 1976 (Table 4). Slight decreases in algal biomass were also noted at all the remaining stations.

The species composition of the phytoplankton remained similar throughout the study period, with general seasonal trends typical of mesotrophic lakes. Bacillariophyceae and Chrysophyceae were dominant during the spring whereas Cyanophyceae were abundant during the summer months. The common species included *Aphanothece, Chrococcus* and *Cyclotella,* which are normally present in non-eutrophic waters and *Melosira, Stephanodiscus* and *Anabaena,* which are characteristic of eutrophic lakes.

Macrophytes

Submersed aquatic plants are extremely prolific in southern Chemung Lake, covering an area of some 430 ha or about 50% of the lake surface. Over 20 plant species have been found in the lake and, of these, Eurasian watermilfoil, Northern watermilfoil and Vallisneria are the most common. The major plant species and year to year changes in relative frequencies are outlined in Table 5. Since the start of the study, there has been a pronounced increase in Eurasian watermilfoil throughout the lake with concurrent reductions in Northern watermilfoil and Vallisneria. This increase is considered to be unrelated to harvester activity since similar trends have occurred in the other lakes of the Kawartha-Trent Waterway.

Plant tissue concentrations of nitrogen and phosphorus ranged between 1.2 to 2.8% and 0.13 to 0.60% dry weight, respectively. These values are generally well above critical limits reported in the literature (7) indicating that plant growth was not restricted by nutrient availability. This would suggest that while increases in ambient nutrient levels should not result in increased biomass production, drastic reductions would be necessary before nutrients would become a limiting factor for plant growth in the lake.

Peak annual biomass values were similar throughout the study period, ranging between 300 g dry weight per m² in 1973 and 400 g dry weight per m² in 1972 (Figure 2). Higher spring biomass values obtained during the latter years of the study reflect the increase in Eurasian milfoil which exhibits an early growth phase compared to the later maturing Vallisneria (Figure 2). In 1971 Vallisneria contributed 38% of the annual dry weight biomass compared to only 8% in 1976. Conversely contributions by the milfoil increased from 7% to 48% over the same period (Table 6).

Since the explosive growth of Eurasian milfoil coincided with the experimental study period, the effects of harvesting on plant biomass were difficult to evaluate. However, plants

TABLE 4. AVERAGE PHYTOPLANKTON BIOMASS EXPRESSED IN AERIAL STANDARD UNITS PER ml.

Year	Station 2 (North)	Station 1 (South)	Station 4 (South)
1972	2950	2400	4700
1973	2350	2900	3600
1975	2950	3700	3050
1976	1750	2100	1750

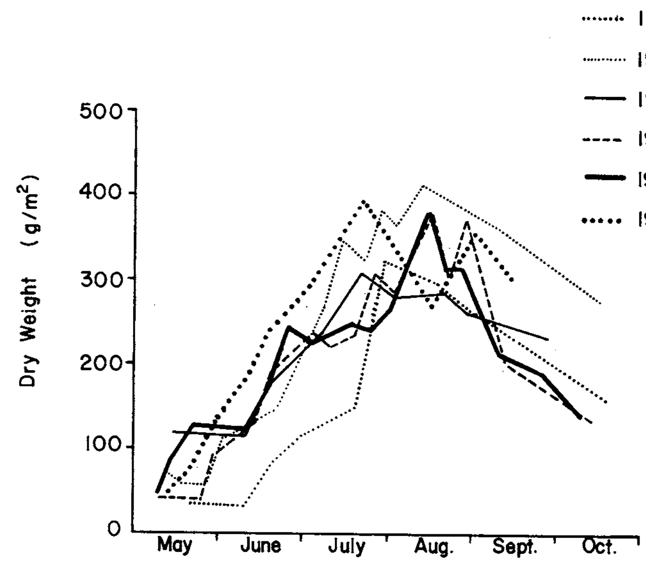

Figure 2. Dry weight of aquatic plants in lower Chemung Lake from 1971 to 1976.

TABLE 5. FREQUENCY OF PLANT SPECIES OCCURRENCE IN SOUTH CHEMUNG LAKE (1971 TO 1976).

Species	Relative Frequency (%) 1971	1972	1973	1974	1975	1976
Vallisneria americana Michx.	21.7	22.2	19.0	16.6	18.0	15.0
Chara sp.	16.0	13.5	11.7	9.4	8.7	9.8
Myriophyllum spp.	13.9	11.0	13.9	16.4	18.7	20.3
Potamogeton zosteriformis Fernald	15.0	13.4	10.5	9.5	7.1	6.7
Najas flexilis (Willd.)	11.3	9.9	9.1	8.7	11.8	5.8
Elodea canadensis Michx.	5.3	8.1	9.6	12.0	11.3	10.7
Potamogeton richardsonii (Benn.) Rydb.	4.9	3.2	3.9	3.4	1.9	2.5
Potamogeton amplifolius Tuckerm.	5.5	2.6	1.9	2.3	1.8	1.4
Ceratophyllum demersum L.	1.8	2.4	1.8	1.7	1.7	1.7
Heteranthra dubia (Jacq.) MacM.	0.8	5.7	6.0	5.3	6.3	8.8
Megalodonta beckii (Torr.) Greene	0.2	0.9	2.7	2.7	3.0	1.6
Potamogeton strictifolius Benn.	1.0	0.3	6.3	5.8	3.2	5.1
Potamogeton pectinatus L.	—	3.5	0.6	2.3	2.2	2.7
Ranunculus sp.	0.2	1.5	0.2	1.0	0.7	1.2
Potamogeton robbinsii Oakes	1.0	0.5	1.2	1.1	0.8	0.9
Potamogeton crispus L.	—	—	0.1	1.1	1.3	1.2
Potamogeton praelongus Wulf.	—	—	0.1	0.2	—	<0.1
Sagittaria sp.	1.4	0.5	0.9	0.5	1.3	1.9
Utricularia vulgaris L.	0.2	0.6	0.7	0.1	0.3	—

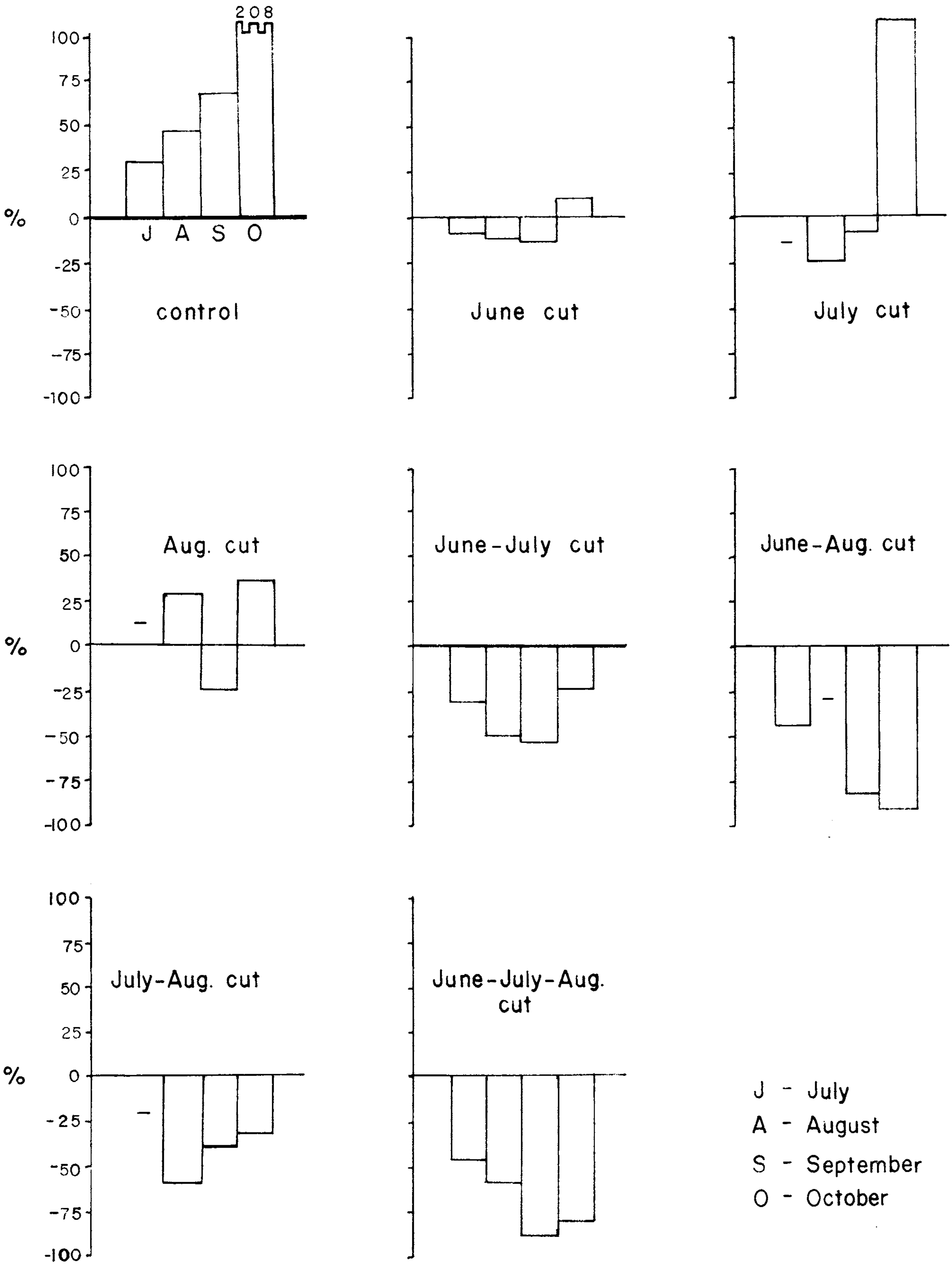

Figure 3. Percentage change in stem numbers after initial June sampling, at experimental cutting plot for Myriophyllum in Chemung Lake in 1975.

TABLE 6. PERCENTAGE CONTRIBUTIONS BY THE VARIOUS AQUATIC PLANT SPECIES TO THE TOTAL ANNUAL BIOMASS (DRY WEIGHT).

Species	1971	1972	1973	1974	1975	1976
Vallisneria americana Michx.	38.3	32.5	34.9	25.6	24.2	7.9
Myriophyllum spp.	6.8	8.7	11.1	29.8	25.9	47.9
Chara sp.	44.5	41.2	38.7	21.6	19.8	24.4
Elodea canadensis Michx.	<1.0	4.0	3.4	3.9	7.2	8.4
Najas flexilis (Willd.)	2.4	1.8	1.5	3.7	11.1	4.2
Heteranthra dubia (Jacq.) MacM.	<1.0	5.9	3.3	3.0	4.4	3.1
Others	6.0	5.9	8.1	12.4	7.4	4.1

in areas harvested since 1973 were noticeably slower in reaching the water surface during 1976 when compared to adjacent non-harvested areas. Similarly, biomass of Eurasian milfoil at a site harvested from 1973 to 1975 increased at approximately one half of the rate of an adjacent non-harvested area during the 1976 season.

To monitor changes in stem densities and rates of regrowth following cutting, a series of experimental plots was established in a pure stand of Eurasian milfoil. The plots were harvested either once, twice or three times during the season and changes in stem numbers and stem heights were compared to control plots. Multiple harvests were most effective in reducing stem numbers. Single harvests resulted in slight increases in stem numbers, although the changes were minor compared to the increases which occurred in the control plots (Figure 3). Similarly, plant heights in most plots did not reach the levels attained by the control plots. One exception was a single cut (June) plot which exceeded the average height of the control plots by 0.1 m by late October. This plot also exhibited the smallest increase in stem numbers of all the single harvest plots.

Fisheries

The Kawartha Lakes, including Chemung Lake, are well known for their excellent fishing, particularly for warm-water game fish such as walleye [*Stizostedion vitreum* (Mitchill)]. Since aquatic plants form an important component of the fish habitat, the Ontario Ministry of Natural Resources carried out detailed studies to investigate the effects of plant removal on the fish populations of Chemung Lake.

Numerically pumpkinseeds [*Lepomis gibbosus* (Linnaeus)] dominated the trapnet returns, followed by yellow perch [*Perca flavescens* (Mitchill)] and walleye. With the exception of yellow perch, population estimates remained consistent over the duration of the study period. Yellow perch catches declined significantly from 1160 catch per 100 net days in 1973 to 75.6 catch per 100 net days in 1975 in southern Chemung Lake and from 779 to 67.8 catch per 100 net days in the northern sector. This decline is considered to be indicative of a stress response although reductions in the populations both in southern and northern Chemung Lake would seemingly exonerate harvester activity as a cause.

Creel data were collected from over 11,000 anglers between 1971 and 1976. Throughout the study period, walleye harvest remained fairly consistent in southern Chemung Lake, ranging between 5.4 and 3.5 fish per ha per 100 days but declined from 2.7 to 0.6 fish per ha per 100 days in the northern sector. Angler effort peaked in 1972 (35.7 angler hr per ha per 100 days in south Chemung and 25.9 angler hr per ha per 100 days in north Chemung) followed by a gradual decline by 1976. The decline in angler effort was somewhat surprising since the walleye harvest, particularly in southern Chemung, remained consistent during this period. Although the exact causes of reduced angler effort are difficult to pinpoint, the invasion of Eurasion milfoil and resultant publicity may have been a contributing factor.

Since harvesting operations can result in the direct loss of fish which are trapped in the vegetation and removed during the harvesting process, random plant samples were collected from the harvester and examined for their fish content. The wet weight ratio of plants to fish was found to be approximately 1000:1 or equivalent to 8.9 kg fish per ha harvested. The fish were small ranging between 12 and 190 mm in length and 2 to 3 g (sample means) in weight. Yellow perch were the most numerous species, accounting for 56% of the total.

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LITERATURE CITED

1. Ahlgren, I. 1977. Role of sediments in process of recovery of a eutrophicated lake. IN: Interactions between sediment and freshwater, H. L. Golterman (ed.), Dr. W. Junk, B. V. Publishers, Hague. 473 p.
2. Brandes, M. 1974. Studies on subsurface movement of effluent from private sewage disposal systems using radioactive and dye tracers. Part 2. Ontario Ministry of the Environment technical report. 54 p.
3. Bristow, J. M. and M. Whitcombe. 1971. The role of roots in the nutrition of aquatic vascular plants. Amer. J. Bot. 58:8-13.
4. Denny, P. 1972. Sites of nutrient absorption in aquatic macrophytes. J. Ecol. 60:819-829.
5. Dillon, P. J. and F. H. Rigler. 1975. A simple method for predicting the capacity of a lake for development based on lake trophic status. J. Fish. Res. Board Can. 32:1519-1531.
6. Fitzgerald, G. 1969. Some factors in the competition or antagonisms among bacteria, algae and aquatic weeds. J. Phycol. 5:351-359.
7. Gerloff, G. C. 1975. Nutritional ecology of nuisance aquatic plants. E.P.A. report No. 660-3-75-027. 79 p.
8. Goulder, R. 1969. Interactions between the rates of production of freshwater macrophytes and phytoplankton in a pond. Oikos 20: 300-309.
9. Hutchison, G. E. 1957. A treatise on Limnology. Vol. 1. John Wiley & Sons Inc., New York. 1015 p.
10. Larsen, D. P., K. W. Malueg, D. W. Shutlz and R. M. Brice. 1975. Response of eutrophic Shagawa Lake, Minnesota, U.S.A., to point source phosphorus reduction. Verh. Internat. Verein. Limnol. 19: 884-892.
11. Neel, J. K., S. A. Peterson and W. L. Smith. 1973. Weed harvest and Lake Nutrient Dynamics. EPA-660/3-73-001.

12. Nicholls, K. H. 1976. Comparative limnology of Harp and Jerry Lakes, adjacent cottaged and uncottaged lakes on southern Ontario's Precambrian Shield. Ontario Ministry of the Environment technical report. 87 p.
13. Ontario Ministry of the Environment. 1975. Outlines of analytical methods. Ontario Ministry of the Environment technical report. 94 p.
14. Peterson, S. A., W. L. Smith and K. W. Malueg. 1974. Full scale harvest of aquatic plants: nutrient removal from a eutrophic lake. Water Poll. Control Fed. 46:697-707.

J. Aquat. Plant Manage. 16: 20-23