Lake Simcoe Environmental Management Strategy

Implementation Program

Status in 1990 of the Dominant Benthic Alga, *Dichotomosiphon tuberosus*, in Lake Simcoe

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STATUS IN 1990 OF THE DOMINANT BENTHIC ALGA
Dichotomosiphon tuberosus
IN LAKE SIMCOE

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for

The Lake Simcoe Environmental
Management Strategy Technical Committee
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LAKE SIMCOE ENVIRONMENTAL MANAGEMENT STRATEGY
IMPLEMENTATION PROGRAM

FOREWORD

This report is one of a series of technical reports prepared in the course of the Lake Simcoe Environmental Management Strategy (LSEMS) Implementation Program. This program is under the direction of the LSEMS Steering Committee, comprised of representatives of the following agencies:

- Ministry of Agriculture, Food and Rural Affairs;
- Ministry of the Environment and Energy;
- Ministry of Natural Resources; and
- Lake Simcoe Region Conservation Authority.

The Lake Simcoe Environmental Management Strategy (LSEMS) studies were initiated in 1981 in response to concern over the loss of a coldwater fishery in Lake Simcoe. The studies concluded that increased urban growth and poor agricultural practices within the drainage basin were filling the lake with excess nutrients. These nutrients promote increased weed growth in the lake with the end result being a decrease in the water's oxygen supply. The "Final Report and Recommendations of the Steering Committee" was released in 1985. The report recommended that a phosphorus control strategy be designed to reduce phosphorus inputs from rural and urban sources. In 1990 the Lake Simcoe Region Conservation Authority was named lead agency to coordinate the LSEMS Implementation Program, a five year plan to improve the water quality of Lake Simcoe. The Conservation Authority will have overall coordination responsibilities as outlined in the LSEMS Cabinet Submission and subsequent agreement (Recommendation E.1). At the completion of the five year plan (1994) a report will be submitted to the Cabinet. This report will outline the activities and progress of the LSEMS Implementation Program during its five years. After reviewing the progress of the program the Cabinet may continue the implementation program.

The goal of the LSEMS Implementation Program is to improve the water quality and natural coldwater fishery of Lake Simcoe by reducing the phosphorus loading to the lake. The LSEMS Implementation Program will initiate remedial measures and control options designed to reduce phosphorus inputs entering Lake Simcoe, monitor the effectiveness of these remedial measures and controls and evaluate the overall response of the lake to this program. Through cost sharing programs, environmental awareness of the public and further studies, the goal of restoring a naturally reproducing coldwater fishery in Lake Simcoe by improving water quality can be reached.

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The material presented in these reports is analytical support information and does not necessarily constitute policy or approved management priorities of the Province or the Conservation Authority and/or the evaluation of the data and findings, should not be based solely on this specific report. Instead they should be analyzed in light of other reports produced within the comprehensive framework of this environmental management strategy and the implementation of the recommendations.

Reference to equipment, brand names or suppliers in this publication is not to be interpreted as an endorsement of that product or supplier by the authors, the Ministries of Agriculture, Food and Rural Affairs, Environment and Energy or Natural Resources or the Lake Simcoe Region Conservation Authority.

EXECUTIVE SUMMARY

Since the presence of the benthic, Macro-algal species *Dichotomosiphon tuberosus* was first identified in Lake Simcoe in 1978 by Ministry of the Environment Staff, three surveys have been conducted by Limnos Limited to document its distribution, standing crop and environmental significance to the lake.

The data reported herein relate to the findings of the third field study conducted in August 1990, together with summaries of and comparisons with results previously reported. More specifically, the objectives for the 1990 field survey were to establish the current distribution within the lake, measure standing crop biomass and determine the tissue content of plant nutrients and selected metals.

In order that the data collected would be directly comparable to previous surveys, the precise transect and sample location, as established by LORAN positioning in 1986, were used. Likewise, specific methods for diver surveys, dredge sample collection of biomass, sample preparation and tissue analyses were followed.

The total area covered by the 'rug-like' growth of *Dichotomosiphon* in 1990 was estimated to be 67.2km^2 for a total of 9.7% of the lake bottom. The mean biomass for thirty locations measured was, wet weight 407g/m^2 and dry weight 87g/m^2. The present organic (LOI) and tissue nitrogen and phosphorus content of samples retained from ten locations were analysed. In addition, two samples were collected from the same station, and three split samples were analysed to measure precision and accuracy. The mean values for the fifteen analyses indicated the organic content to be 58.2%. The mean tissue nitrogen was 2.45% on a dry weight basis and 4.2% on an ash-free basis. Total dry weight phosphorus was 0.102% and 0.176% ash-free.

Five metals were requested to indicate the status of uptake of iron and four heavy metals. The results from the same fifteen samples reported concentrations of Fe 0.39%, Cd 1.85µg/g, Cr 4.9µg/g, Cu 8.07µg/g and Pb 18.6µg/g.

Comparison with findings of previous years documented distribution to occupy essentially the same areas as previously mapped but some new areas and extensions to those previously documented were added. By comparison, the estimated total bottom covered in 1983 was 56km^2 and 67.2km^2 in 1990. Biomass was generally higher in 1990

than previous measurements. When values for 21 locations precisely located by LORAN are compared, an increase of 215% in wet weight and 240% in dry weight was found. Based on the mean biomass, results from each of the three years indicate the highest biomass in 1990 and the lowest in 1986.

The dry weight values for total nitrogen are inconsistent between sampling in 1983 (1.26%) and 1990 (2.45%), whereas values for total phosphorus are in agreement at about 0.1%. When calculated on an ash-free basis, the low organic content of the 1983 samples appears to produce artificially high values. The 1990 results establish the tissue content (% organic) for nitrogen to be 4.2% and phosphorus 0.18% for an N:P ratio of 23:1.

An estimate of the total biomass for the lake and the tissue nutrients and metals they contained was calculated. The total standing crop was estimated at 5,846t dry weight. The plant tissues were estimated to contain 143t of nitrogen, 5.96t of phosphorus and 22.8t of iron in 1990.

No analyses for heavy metals had been done previously on tissue samples. When compared to sediment analyses reported for the main basin of the lake, Cd in tissues was double the sediment value suggesting biomagnification. The remainder was less than the sediment concentration. A comparison with tissue levels of metals in *Cladophora* from the lower Great Lakes indicates lower values in *Dichotomosiphon* with the exception of Pb.

In summary, *Dichotomosiphon* appears to be an integral part of the aquatic community fully occupying the available niche. It may be subject to seasonal variation in standing crop. It incorporates a significant mass of plant nutrients but it is not known whether these are extracted from the water of the sediments. If significant sediment nutrient resources are mobilized, it may serve as a pump to move phosphorus which might otherwise be unavailable into an active biological system. Bottom fauna studies (Limnos 1986) indicate that the production of *Gammarus*, an important fish food organism, is greatly enhanced by its presence. It does not appear to be an important contributor of heavy metals to the ecosystem.

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1. INTRODUCTION

The macro-algal species *Dichotomosiphon tuberosus* (A. Br.) Ernst 1902, was identified from sediment samples collected in Lake Simcoe by Ontario Ministry of the Environment staff in September, 1978. Subsequent collections suggested that it might have extensively colonized the sediments and in 1983 a contract was established with Limnos Limited to undertake a preliminary survey of the distribution, biomass and tissue nutrient concentration of the alga in the Lake. The survey was completed in August and September of that year and the findings subsequently reported (Limnos 1984), (L.S.E.M.S. 1985).

The initial study found that *Dichotomosiphon* was established over extensive areas of bottom along the eastern and northeastern shoreline, and that the plant tissues contained a significant quantity of the lake's biologically active nitrogen and phosphorus resources. In 1986 a second survey was contracted having the objectives of more accurately delineating the areas of growth and biomass, and to assess the effect of the benthic algal production on bottom fauna species and numbers. Tissue analyses were not included as a requirement of the contract so that only limited data (3 samples) were subsequently analysed and reported.

In establishing the second survey, most of the transects surveyed in 1983 were re-run and their precise locations established using LORAN C navigation equipment to provide a permanent record of the locations and course. Likewise, all stations where biomass samples were collected in 1986 were located in order that any future survey having the objective of measuring changes in distribution, biomass or tissue nutrients could return to these locations to collect directly comparable data.

The findings of the 1983 and 1986 surveys reported that *Dichotomosiphon* was found to cover about $58km^2$ or 8% of the lake bottom principally adjacent to the easterly and northerly shorelines. Growth occurred in depths from 3m to 10m on bottoms composed of various combinations of sand, silt and mud. While biomass samples were not taken from precisely comparable locations in the first two surveys, the estimate of overall growth in the lake was in reasonable agreement, 1.28×10^3 tonnes in 1983 and 1.05×10^3 in 1986 as measured on an ash-free basis.

The presence of the algal mat was found to enhance the population of *Gammarus fasciatus* while small numbers of other bottom fauna were found in approximately equal numbers within and outside the algal mat.

In 1990 a third survey was contracted with the general objective of repeating the collections and analyses previously reported to assess whether changes had occurred in the interval.

The findings of the 1990 study and comparative evaluations with previous results are the subject of the following report as established by the specific objectives reported hereafter.

2. OBJECTIVES - 1990 Survey

a) Distribution

To duplicate the survey technology used over each of the transects run in 1986 using the LORAN-identified courses run at that time.

From the data reported by diver observation, to plot the distribution of the alga on the lake bottom and to compare these findings.

In addition, to examine other areas of the lake where suitable depth and sediment type suggested possible growth areas, principally along the northwesterly and western shores.

b) Biomass

A minimum of 27 biomass samples were to be collected from each of the LORAN co-ordinates sampled during the 1986 survey. All samples were to be collected in the same way (Ekman dredge) and processed to provide data reported as wet weight, dry weight, and ash-free dry weight to provide directly comparable data.

c) Tissue Analyses

Samples from a total of 10 locations were to be selected and submitted to a qualified laboratory. Replicated analyses were to be conducted on five of these locations either on a split sample from that location or a replicate sample taken at that site. Analyses to be conducted included, loss on ignition (LOI), total phosphorus, total nitrogen and five selected metals.

d) Other Observations, Assessments and Relevant Literature

The objectives proposed that other data, observations or literature pertinent to the study be reported as background to building a body of knowledge relating to the presence and significance of this algal species in Lake Simcoe.

3. METHODS

3.1 Field Procedures

The field sampling methodology closely approximated the methods used for surveys in 1983 and 1986. The studies of distribution were all commenced in mid-August and completed late August or early September. In order that the diver observations corresponded to the area of previous observations, a number of the 1983 transects which had been established on a hydrographic chart using known beginning positions and compass bearing for location were re-positioned during the 1986 survey using LORAN C.

Likewise, the precise location of all samples collected for biomass and tissue nutrients was individually marked with a LORAN position. By these means it was possible in 1990 to repeat the transects previously used to record presence of the alga and to duplicate the location of sampling for biomass and tissue nutrients.

3.2 Environmental Conditions

During the course of the survey, data was collected on the general environmental conditions present at that time including temperature at the top and bottom and secchi depth. These data were collected at the deep end of each run by the diver using a hand-held thermometer, and the secchi depth was recorded at the same location.

Bottom type as recorded in field notes was observational and described as boulder, gravel, sand, silt, organic mud or combinations thereof. Where aquatic macrophytes were encountered, the species present and their estimated percent composition were recorded. Other comments indicated the presence of clams, crayfish or other biota. Fish were not seen frequently, probably because they avoided the diver and sled and the visibility was generally limited to about 2m.

3.3 Distribution

The following specific methods were employed in collecting the 1990 distribution data. Equipment used included a 5.5m x 2.5m (18' x 8') barge powered by a 65 H.P. outboard. A diver tow-sled (App. 1) was used to tow the diver about 35m behind the vessel at a speed of approximately 3km/hr. The tow-sled was equipped with a doorbell-signal system, so that communication could be maintained with the barge. A series of signals was established to provide the following information - all well, faster, slower, emergency, stop, start, beginning of alga growth, end of alga growth.

While conducting transect surveys, two people operated in the vessel, one being a second diver to perform alternate dives and for emergency backup, and the boat operator. The second diver/biologist on the vessel established the LORAN course and made notes on a field sheet of LORAN positions each time the diver signalled the beginning and end of alga growth on the bottom. At the end of each transect, the diver who had performed that survey made immediate field notes of specific observations such as the general colour and health of the alga, continuity, length of filament, type of bottom and any general observations of aquatic life observed within and outside the growth beds.

By these means, 31 transects were surveyed which corresponded directly to the locations observed in 1986 as positioned by LORAN and conformed generally to those surveyed in 1983. In addition to the repetition of transects surveyed previously, several areas of the lake where the depth suggested potential conditions for growth were observed either by sled or free-dive observation.

In all, a total of 47km of the Lake Simcoe bottom was observed by these means over transects or spot dive locations within the lake.

The distribution and areal coverage of *Dichotomosiphon* on the lake bottom was plotted using the LORAN co-ordinates recorded from the field data logs for each transect. The specific locations of the beginning and end of growth areas were recorded on a LORAN chart supplied by the Ministry of Natural Resources (Allen, personal communication) which the Ministry have developed for the lake. The beginning and end points of observed growth were connected on the chart to delineate areas of production. Where rock, gravel or soft mud bottom unsuitable for growth occurred between points of observation, they were considered to be non-productive.

When the areas of growth had been so plotted on the chart, a planimeter was used to determine the total area of *Dichotomosiphon* production.

3.4 Biomass

Twenty-six sample locations were used to collect biomass samples and a duplicate sample was taken at four of these stations. Twenty-one of these stations were replicates of locations delineated by LORAN co-ordinates previously sampled in 1986.

The samples were collected using the same procedures as previously used with the exception that seven individual collections using a 15.24cm x 15.24cm (6" x 6") Ekman dredge were made, rather than three samples using a 22.86cm x 22.86cm (9" x 9") Ekman dredge as in previous surveys. The total area sampled at each location however by the two procedures was approximately equal.

Samples collected were carefully washed in a container with a 20-mesh screen bottom to remove the sediment, then picked by hand to remove extraneous material such as gravel or clam shells. The seven dredge samples were then pooled to form a composite sample and spun in a salad spinner to remove surficial water. The alga was also squeezed by hand to remove any additional free water and placed in a labelled plastic bag in an iced container for wet weight determination at the end of each sampling day.

Wet weights were determined using an O'Haus balance and weighed to the nearest 0.1g. All samples were then air-dried in mesh-bottom stacking trays in a shaded location. When no further weight reduction occurred, they were re-weighed to determine the dry weight of alga collected at each sample location.

3.5 Tissue Analyses

Air-dried samples from ten locations sampled for biomass determinations were retained for tissue analyses. Replicate analyses were conducted on three split samples and two separate samples collected from the same location. Determinations performed included, dry weight, loss on ignition, total nitrogen, total phosphorus and total Fe, Cd, Cr, Cu and Pb on the fifteen samples submitted. All tissue analyses were performed by the laboratory of the Environmental Applications Group Limited.

4. RESULTS - 1990 Survey

4.1 Environmental Conditions

Temperatures on the bottom adjacent to algal growth were found to vary between 15°C and 22°C. (Table I). Examination of the data indicates that on August 22nd and 23rd there was an intrusion of cool water (15°C - 16°C) along the bottom in a pool extending from the open water stations between Georgina Island and Thorah Island to shore from Pefferlaw Creek and northward towards Beaverton. The divers noted the cold water as occurring only in the bottom meter. Less variable temperatures of 19°C to 22°C on the bottom were noted on other days and at other locations. Surface waters were normally 1°C to 3°C warmer than bottom waters as measured at the deep end of transects at 8m to 10m depths.

Secchi depth measured at the deep end of the twenty-six transects surveyed varied from 2.2m to 3.9m. The lowest transparencies were recorded in the Pefferlaw area and the highest in the vicinity of Thorah Island.

Table I. Representative Temperature and Light Conditions at Selected Stations in Lake Simcoe.

Date	Transect	Temp.(°C)		Secchi
		Top [1]	Bottom [2]	Depth(m)
Aug. 20	B3	22.1	-	2.5
Aug. 21	A1	20.7	-	3.1
	A2	21.0	-	3.1
	A3	21.9	-	3.1
	A4	21.5	-	2.4
Aug.22	A5	22.0	22.0	-
	B1	21.5	-	2.8
	B5	21.5	16.0	2.3
	B6	21.5	15.5	2.8
Aug.23	B2	21.5	19.5	2.2
	B4	21.0	-	2.4
	B8	21.5	15.0	2.6
	C4	22.5	21.5	2.4
	C5	22.0	21.5	3.2
	C3	22.0	15.5	3.4
	B7	22.0	16.0	3.0
Aug. 24	C2	21.5	19.0	3.0
	C1	22.0	21.5	3.9
	C6	23.0	21.0	3.9
	D1	23.0	21.0	3.5
	D2	22.5	21.5	3.0
Aug. 25	D3	23.5	21.5	3.2
	D4	24.0	21.5	3.0
	D5	24.5	22.0	2.5
	E1	23.5	21.5	-
	E2	23.5	21.5	3.5
Aug.29	E3	-	21.0	3.0
	E43.0	-	-	
	Mean:	22.2	19.8	3.0

[1] Temperatures measured 0.5m from surface
[2] Temperatures measured 0.5m from bottom

4.2 Distribution

The distribution of *Dichotomosiphon* was assessed by diver observation along the transects plotted on Figure 1. The general location, transect number and precise co-ordinates for the beginning and end of each transect are recorded in Appendix 2.

The results of the distribution as determined by the methods described are plotted on Figure 2.

The total area of lake bottom supporting growth of the alga in 1990 is estimated to be $67.2km^2$.

The diver's log notes indicate that growth over much of the area was a continuous, lush green carpet. In some locations where boulder or gravel conditions were present, pockets of suitable sediment existed which supported discontinuous patches of lush growth. In areas of marginal conditions of depth or sediment type, less vigorous growth was noted as characterized by short filament length, patchy distribution and either a brown or light green appearance.

In general, the strongest growth occurred in depths of 4m to 7m which would appear to be optimal under Lake Simcoe conditions.

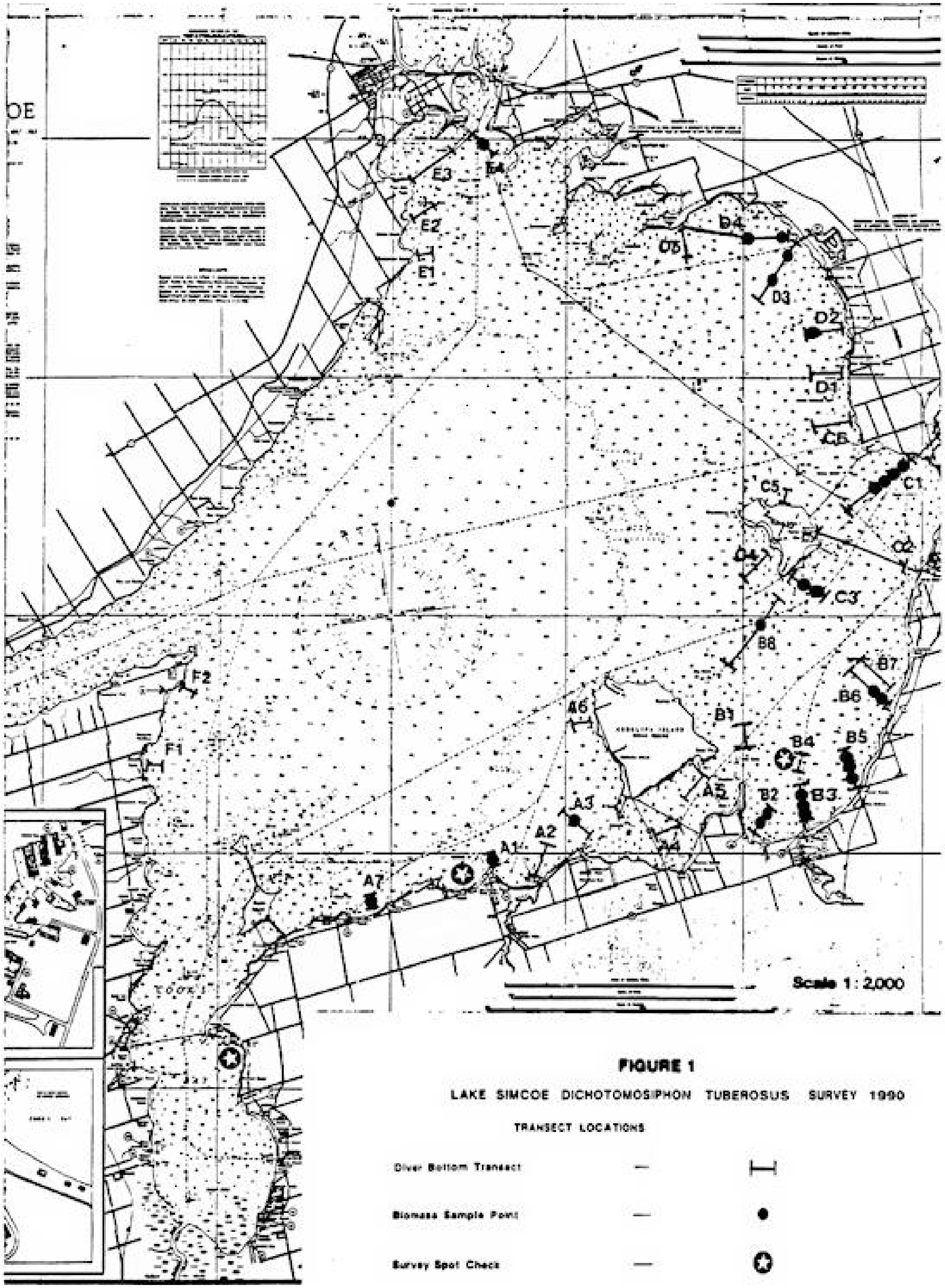

FIGURE 1

LAKE SIMCOE DICHOTOMOSIPHON TUBEROSUS SURVEY 1990

TRANSECT LOCATIONS

Diver Bottom Transect	—	⊢⊣
Biomass Sample Point	—	●
Survey Spot Check	—	✪

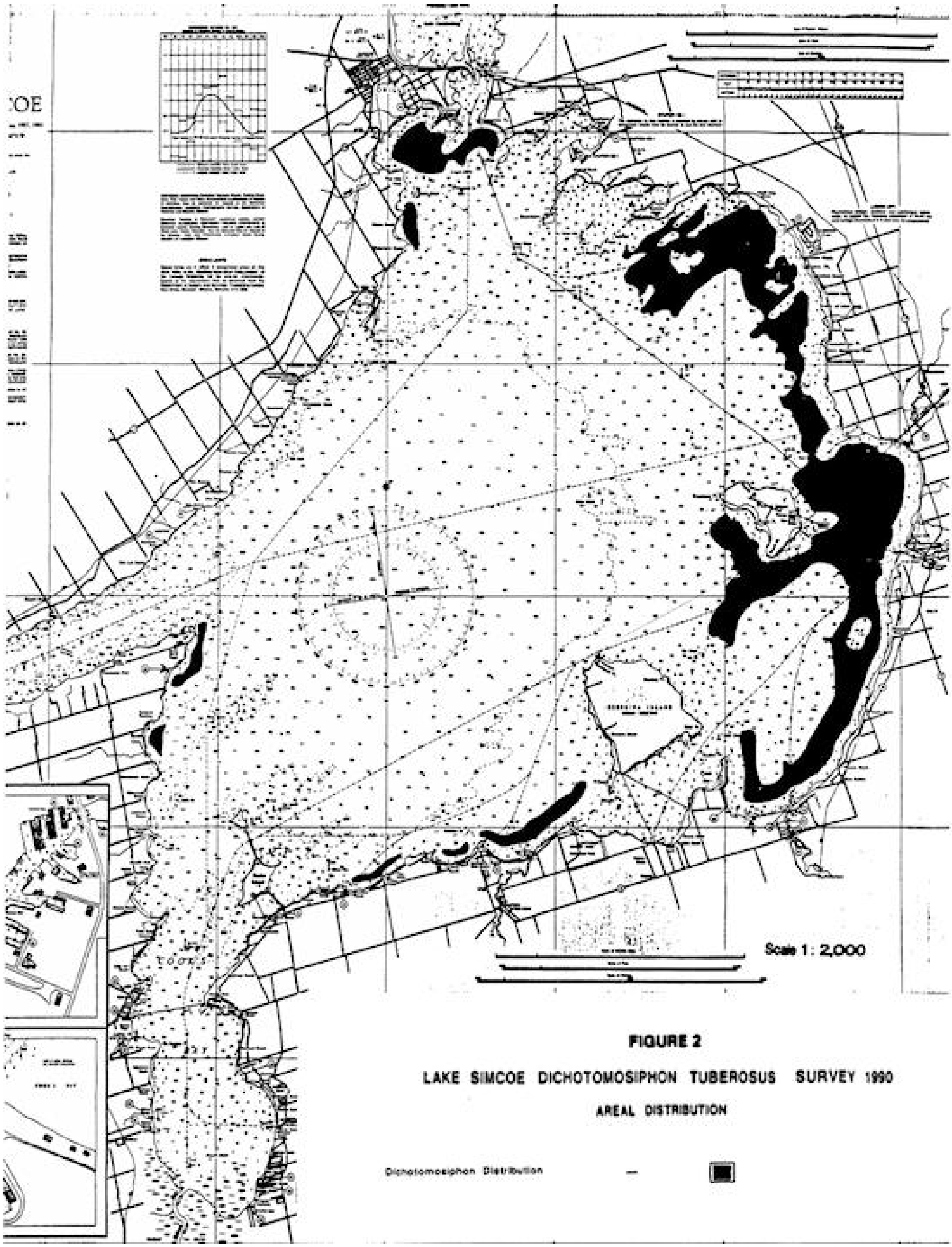

FIGURE 2

LAKE SIMCOE DICHOTOMOSIPHON TUBEROSUS SURVEY 1990

AREAL DISTRIBUTION

Dichotomosiphon Distribution — ■

4.3 Biomass

The results of the series of 30 biomass determinations are presented in Table II. Values measured on a wet weight basis ranged from $81g/m^2$ to $948g/m^2$ with a mean of $407g/m^2$. When the samples were air-dried, a mean biomass dry weight of $87g/m^2$ was determined with values ranging from $14g/m^2$ to $198g/m^2$. This indicates the wet sample consisted of 22.3% dry matter and 77.7% moisture with a range of individual values for the thirty samples varying between 8% and 43% dry matter.

Difficulty was experienced in obtaining quantitative values for biomass in previously reported surveys as there was considerable variability in the moisture content of wet samples and a major difference in organic content.

In order to resolve this problem, all samples in the 1990 collections were washed until no further turbidity was apparent in the wash water and the algal mass was hand squeezed until no further surface moisture was expressed. In addition, replicate samples were taken from four sample sites to determine the sampling variability at any one site. The results of replicate sampling for biomass are reported in Table III.

It will be noted that for the four samples evaluated, a significant variability was noted for wet weight values with much more consistency appearing in dry weight replicates.

Table II. LAKE SIMCOE DICHOTOMOSIPHON TUBEROSUS BIOMASS (g/m²).

Date	General Location	Transect Sample	(m) Depth	LORAN Location		Wet Weight	Dry Weight	% D.M.
Aug. 28	Trent Canal	C1/1	4.5	15924.6 /	59113.4	262	76	29
		C1/2	5.2	43.7/	11.8	516	141	27
		C1/3	5.5	44.8/	10.5	409	108	26
		C1/4		46.6/	06.8	295	78	26
	McRae Shoal	B6/1	5.8	75.0/	14.3	452	123	27
		B6/2	6.8	74.1/	12.5	390	92	24
		C3/1	4.1	15960.3/	59098.9	160	35	22
		C3/2*	6.0	60.8/	00.3	329	83	25
		C3/2*	6.0	60.8/	00.3	301	83	28
	Thorah Is.	B8/1	8.0	67.4/	89.7	81	19	24
Aug. 29	S.W. Lagoon City	D3/1	5.9	15.2/	90.0	208	90	43
		D3/2	8.2	19.3/	86.3	436	130	30
	Pier Lagoon City	D4/1	4.9	13.6/	88.9	257	79	31
		D4/2	6.8	15.4/	80.6	499	147	30
	Cedar Pt.	E4/1*	8.0	10.2/	28.3	387	61	16
		E4/1*	8.0	10.2/	28.3	289	60	21
Aug. 30	Pefferlaw Bay	B2/1	4.3	15994.9/	59092.5	920	198	22
		B2/2	5.3	94.0/	93.8	744	116	16
		B2/3	6.5	92.8/	94.6	585	110	19
	Pefferlaw R.	B3/1	4.8	15992.0/	59102.7	120	19	16
		B3/2*	6.4	90.8/	01.7	490	80	16
		B3/2*	6.4	90.8/	01.7	948	97	10
		B3/3	7.0	90.2/	01.7	492	44	8
	Thorah Beach	B5/1	4.8	85.7/	10.9	511	95	19
		B5/2	6.0	84.6/	10.0	615	157	26
		B5/3	6.8	83.5/	09.3	446	99	22
Aug. 31	Jacksons Pt.	A1/1*		16005.0/	59039.6	289	40	14
		A1/1*		16005.0/	59039.6	308	43	14
	Sibbald Pt.	A3/1		97.5/	57.3	84	14	17
	Willow Beach	A7/1		13.0/	15.7	391	81	21
	Mean(g/m²):					407	87	22.3

* Replicate Samples

Table III. Values Determined for Replicate Samples*.

Station	Replicate No.	Wet Wt. g/m^2	Dry Wt. g/m^2	% DM	AFWD/g/m^2
C3/2	1	329	83	22	53.7
	2	301	83	25	53.7
E4	1	387	61	16	45.8
	2	289	60	21	44.4
B3/2	1	490	80	16	NA**
	2	980	97	10	NA**
A1/1	1	289	40	14	NA**
	2	308	43	14	NA**

* Each sample a composite of 7,232 cm^2 (36in.^{2}) Ekman Dredge grabs expressed in g/m^2

** Not analysed

The reason appears to be inconsistency in water extraction as quite uniform results were found in values for the dry matter replicates.

These observations also suggest a rather uniform biomass on the bottom in the stations sampled as wide variations in results did not occur from patchy distribution on the bottom.

4.4 Tissue Analyses

Analyses were conducted on fifteen samples. These samples were comprised of dry material submitted representing ten individual stations. At two stations, a duplicate set of samples was collected and submitted as separate samples, and duplicate analyses were conducted on three samples from different locations. By these means, it was possible to obtain some measure of variability of tissue content at one station and precision of analyses within the laboratory.

Table IV presents the results of the fifteen analyses for LOI (% organic), total N, total P and organic N and P.

The organic content ranged from 35% to 75% with a mean of 58.2%. Tissue nutrients indicated total nitrogen and phosphorus to have a mean value of 2.45% and 0.102%, respectively. The range of values noted for nitrogen was 1.38% to 4.38% and phosphorus 0.050% to 0.151%.

Because the inorganic component of the samples varies considerably (i.e. LOI

Table IV. Summary of Tissue Analyses - Tissue Nutrients.

Location	Date	% Org.(LOI)	% Total N	% Org. N	% Total P	% Org. P
C 3/2+	Aug. 28	64.7	1.88	2.9	0.050	0.077
C 3/2+	Aug. 28	64.1	1.88	2.9	0.088	0.137
C 1/2	Aug. 28	35.6	1.54	4.3	0.061	0.171
E 4	Aug. 29	64.2	3.13	4.9	0.122	0.190
D 4/2*	Aug. 29	41.2	1.63	4.0	0.082	0.199
D 4/2*	Aug. 29	46.3	1.50	3.2	0.068	0.147
D 3/2	Aug. 29	36.6	2.25	6.1	0.067	0.183
B 3/2+	Aug. 30	75.1	4.13	5.5	0.142	0.189
B 3/2+	Aug. 30	74.0	4.38	5.9	0.137	0.185
B 2/1*	Aug. 30	61.5	2.25	3.7	0.127	0.206
B 2/1*	Aug. 30	71.0	2.50	3.5	0.117	0.165
B 5/2*	Aug. 30	47.5	1.72	3.6	0.084	0.177
B 5/2*	Aug. 30	62.0	1.38	2.2	0.121	0.195
A 1	Aug. 31	70.6	3.75	5.3	0.151	0.214
A 6/1	Aug. 31	58.5	2.75	4.7	0.117	0.200
Mean:		58.2	2.45	4.2	0.102	0.176

\+ Same station sampled twice

* Split sample

n = 15

values), the tissue nutrient composition of the samples was recalculated on an ash-free-dry weight (AFWD) basis and reported as %organic N and P. The mean value of organic nitrogen was 4.2% with a range of 2.9% to 5.9%, and the mean value of organic phosphorus was 0.176% with a range of 0.77% to 0.214%. It will be noted that as anticipated, AFWD values are less variable than those based on dry weight as the effect of extraneous inorganics is reduced.

Dichotomosiphon is thought to accumulate iron both internally and externally to its cell structure. Little is known of its propensity to accumulate other metals and as the lake is known to have received discharges of some metals from industrial sources, analyses for Fe, Cd, Cr, Cu and Pb were conducted on the same samples submitted for nutrient determination. The results of these analyses are reported in Table V.

Iron was found at high levels as anticipated. The mean concentration was 0.39% and somewhat variable, ranging from 0.23% to 0.75%. The remaining metals were quite consistent in sample to sample concentration, reproducibility in both split samples and concentration in two samples from the same site. The mean concentration of tissue metals was found to be Cd 1.55µg/g, Cr 4.69µg/g, Cu 8.07 µg/g and Pb 18.6µg/g.

Table V. Summary of Tissue Analyses - Metals.

Location	Date	Fe %	Cd µg/g	Cr µg/q	Cu µg/gg	Pb µg/g
C 3/2+	Aug. 28	0.23	2.2	4.8	7.2	21
C 3/2+	Aug. 28	0.25	1.9	4.8	7.4	18
C 1/2	Aug. 28	0.42	1.8	5.3	7.3	16
E 4	Aug. 29	0.46	2.0	7.8	7.8	18
D 4/2*	Aug. 29	0.25	1.3	4.5	7.6	13
D 4/2*	Aug. 29	0.30	1.7	4.5	7.9	17
D 3/2	Aug. 29	0.36	1.3	3.1	5.2	13
B 3/2+	Aug. 30	0.75	1.7	3.3	10.0	22
B 3/2 +	Aug. 30	0.75	1.5	3.2	10.0	21
B 2/1*	Aug. 30	0.28	2.0	4.9	7.8	19
B 2/1*	Aug. 30	0.25	1.7	5.2	7.7	16
B 5/2*	Aug. 30	0.46	1.9	5.8	8.7	17
B 5/2*	Aug. 30	0.47	1.9	5.0	8.3	18
A 1	Aug. 31	0.43	2.5	3.5	10.0	27
A 6/1	Aug. 31	0.25	2.4	4.6	8.2	23
Mean:		0.39	1.85	4.69	8.07	18.6

\+ Same station sampled twice

* Split sample

n = 15

5. COMPARISONS BETWEEN YEARS

As noted earlier, stations sampled in 1983 for biomass and tissue analyses were in the same general locations as LORAN fixed position used in 1986 and 1990. For this reason, comparison of averaged data in each of the three years may be used to assess whether changes are occurring in the *Dichotomosiphon* production in the lake. Comparative data as available from the three years is reported in Table VI.

5.1 Environmental Conditions

Environmental conditions for surface and bottom temperatures reported in 1983 and 1990 show that essentially the same surface temperatures occurred. The mean bottom temperature was normally found to be a degree or two colder than the surface at an 8m to 10m depth. It is of interest to note that in 1990 an intrusion of cool water in the order of 15°C to 16°C was found to have occurred on August 22 and 23 in the bottom one meter resulting in a differential of 6°C between the surface and the bottom.

A mean light penetration of 3.0m as measured by Secchi depth was found in 1983 and 1990. As noted in 1983, transparency is somewhat greater in the lake north of Thorah Island.

Table VI. Comparison of Survey Data by Year.

	1983		1986		1990	
Environmental						
Temperature °C Top	22.5		-		22.2	
Bottom	21.8		-		19.8	
Secchi Depth - m	3.0		-		3.0	

Biomass - g/m^2						
Wet Wt.	282	(42)	193	(18)	407	(30)
Dry Wt.	104	(42)	40	(18)	87	(30)
AFWD	23.7	(42)			50.6	(30)
% Dry Matter	36.9	(41)	20.7	(18)	22.3	(30)
Tissue Nutrients %						
Organic(LOI)	22.0	(11)	47.5	(3)	58.2	(15)
Ash Free Dry Wt.	22.8	(11)	-		51.0	(15)
Total Nitrogen	1.26	(11)	1.0	(3)	2.45	(15)
Organic Nitrogen	5.93	(11)	2.1	(3)	4.20	(15)
Total Phosphorus	0.11	(11)	0.95	(3)	0.10	(15)
Organic Phosphorus	0.52	(11)	0.20	(3)	0.18	(15)
Total Org.(TOC)	50.97	(11)	-		-	

5.2 Distribution

The general pattern of distribution of *Dichotomosiphon* was found to be much the same in 1990 as in the two previous surveys. The principal growth area occurs up the easterly shore from Jacksons Point to McGinnis Point. A significant area also occurs on the bottom in waters fronting on Orillia.

Some variances from previous surveys were noted. The alga was found along the shoreline in the Jacksons Point to Georgina Island vicinity in 1983 and 1990 but not in 1986. An extenstion of growth was noted in 1990 along the southwesterly shore of Thorah Island that had not been previously described. Observations had not been previously made of the bottom on the west shore south of Big Bay Point. *Dichotomosiphon* was found to grow here in the rather narrow band of bottom that is an appropriate depth for growth. It is of interest to note that production in this area co-existed with at least seven species of aquatic macrophytes. Divers had noted mixtures of *Dichotomosiphon* and *Chara* sp. in other growth areas, but not in conjunction with vascular plant species.

Further observations were made of the bottom in Cook's Bay where extensive areas of suitable depth occur, but no *Dichotomosiphon* was found. It is believed that soft sediments and reduced light preclude its development in this embayment of the lake.

The total area of growth reported during the three years was:

1983: $56km^2$

1986: $58km^2$

1990: $67km^2$

While some extension of growth area has been recorded in each survey, this probably represents improved survey techniques and the addition of growth areas not previously surveyed rather than an expanded area of growth. It would be our conclusion that distribution of the species is rigidly constrained by bottom type and available light and that it appears to fully occupy the available habitat.

5.3 Biomass

The results of biomass determinations made over the three years are somewhat variable and for this reason, difficult to determine whether changes have occurred between years or from location to location. (Table VI).

In the initial sampling in 1983, mean biomass values for 42 stations were wet weight $252g/m^2$, dry weight $104g/m^2$ and percentage of dry matter, 36.9. Samples were not considered to be washed as well as in subsequent years to remove inorganic sediments and clam shell fragments. This would appear to explain a higher dry weight percentage and lower organic content. Sampling from identical stations in 1986 and 1990 resulted in comparable percent moisture levels in wet weight to dry weight values at 20.7% and 22.3%, respectively. (Table VII).

Table VII. Biomass Values of Directly Comparable Stations 1986 - 1990.

Station	Wet Weight		Dry Weight	
	1986	1990	1986	1990
B3/1	237	120	50	19
B3/2	150	490	26	80
B3/3	51	948	8	97
B2/1	439	920	83	198
B2/2	265	744	56	116
B2/3	60	585	10	110
B5/1	287	511	65	95
B5/2	160	615	33	157
B5/3	356	446	61	99
B6/1	255	452	62	123
B6/2	302	390	58	92
B8/1	92	81	20	19
C1/1	286	262		
C1/2	302	516		
C1/3	10	409		
D3/1	128	208		
D3/2	233	436	43	130
D4/1	160	257	43	79
D4/2	83	499	24	147
C3/1	77	160	21	35
C3/2	217	315		
Mean g/m^2	197.6	445.9	41.4	99.6
Increase:	215%		240%	
	n =21		n = 16	

Unfortunately, the terms of reference for the 1986 study did not include analyses for tissue nutrients and LOI analyses were not performed which would have enabled comparisons on an ash-free basis.

In 1986 and 1990, 21 values for wet weight and 16 dry weight determinations were made for directly comparable locations. (Table VII) The wet weight values were 2.15% greater in 1990 (197.6g/m^2 to 445.9g/m^2) and the dry weight values 240% greater (44.4g/m^2 to 99.6g/m^2).

On a whole lake sample basis, the value for dry weight is somewhat less in 1990 than in 1983 (104g/m^2 to 87g/m^2), however the ash-free dry weights for samples are higher (51.0% to 22.8%). When the contribution of inorganic solids to the dry weight results in 1983 is removed, the standing crop in 1990 is greater than previous measurements (1990: 50.6g/m^2 vs 1983: 23.7g/m^2).

We conclude, therefore, that the standing crop of *Dichotomosiphon* in Lake Simcoe was greater in 1990 than during either of the previous two surveys years.

5.4 Tissue Nutrient Analyses

A comparison of values for tissue nutrients shows some discrepancies between values reported in 1983 and 1990. This is not entirely unexpected as the method of cleaning samples and the sampling stations used were not directly comparable. In an effort to evaluate analytical precision, replicate samples were analysed from two locations and split samples for three other stations in 1990. It will be noted that the results reported for Total N for both the replicate and split samples are in good agreement. The results of comparable analyses for Total P show less precision. (Table IV).

In considering wherein lies the more accurate value of tissue nutrient content, we are inclined to accept the 1990 values as the more accurate result, as samples analysed were almost 60% organic material rather than 22% of the 1983 samples.

It is of interest to note that the tissue phosphorus concentration of dry alga samples (0.102%) is almost identical to the sediment concentration (0.105%) in the main lake basin as reported by Johnson and Nicholls (1988).

5.5 Tissue Metal Analyses

The unique feature of apparent iron deposition at the location of branching and amber-coloured rhizoids suggest that a high iron content of plant biomass would be expected. (Nicholls and Fung 1982). Essentially similar tissue values were reported by our studies in 1983 (0.37%) as in 1990 (0.39%). These values are about an order of magnitude higher than the tissue content reported for Chemung Lake macrophytes (Limnos 1977). Iron analyses have been reported for samples of the macro-attached alga *Cladophora glomerata* on a few samples from Lake Simcoe indicating a range of 0.2 to 0.3% (Jackson, personal communication). Ontario Hydro have also reported on the iron content of *Cladophora* from control stations in Lake Ontario and Lake Erie where levels were found to be 0.31% and 0.34%.

These observations suggest that *Dichotomosiphon* accumulates about ten times the quantity incorporated by aquatic vascular plants and the macro-alga *Chara* sp., but not significantly more than *Cladophora glomerata*.

Fifteen analyses were performed on the same sample series used for tissue nutrients for Cd, Cr, Cu and Pb. This was requested as core samples analysed for these metals had been found to increase with time (Johnson and Nicholls 1988).

No previous information is available on the heavy metal content of *Dichotomosiphon*. In order to evaluate the significance of the values found, a comparison is made with the content of the sediments of the lake to determine whether biomagnification has occurred. Likewise, the tissue content is compared to *Cladophora* to evaluate whether unusual uptakes of these metals is characteristic of the alga or its environment.

Values for the heavy metal content of Lake Simcoe recent sediments in the main basin of the lake and *Dichotomosiphon* and *Cladophora* from control stations in Lake Ontario and Lake Erie are presented in Table VIII.

It will be noted that with the exception of Cd, the concentration of metals in the alga is much lower than the sediment upon which it grows. The mean tissue concentration for Cd is double that reported for the sediment. Cadmium is the only metal of those analysed known to bio-accumulate, and it would appear that this phenomenon has occurred in *Dichotomosiphon.*

When the four heavy metal concentrations of *Dichotomosiphon* tissue in Lake Simcoe are compared to values reported for *Cladophora* in the lower Great Lakes (Ontario Hydro 1981), concentration of Cd, Cr and Cu are lower in *Dichotomosiphon*, but in a similar range. Lead is notably higher and while less than the sediment value, it appears high for aquatic biological materials.

Table VIII. Heavy Metal Concentrations - Lake Simcoe Sediments, Lake Simcoe *Dichotomosiphon*, Lake Ontario and Lake Erie *Cladophora*.

		μg/g			
		Cd	Cr	Cu	Pb
Sediment*	(Main Basin)	0.90	80.7	25.5	82.6
Dichotomosiphon		1.85	4.69	8.07	18.6
Cladophora **	L. Ontario	2.1	12.4	13	5.0
	L. Erie	3.7	6.4	60	5.0

* Johnson and Nicholls, 1988

** Ontario Hydro, 1981

6. WHOLE LAKE EFFECTS

As documented in previous sections of this report, values, to the accuracy of the survey techniques and analytical data reported, enable calculations of the total area of the lake bottom influenced by *Dichotomosiphon* growth, the total biomass and the total content of nutrients and metals bound by the tissues. Whole lake values determined from data collected in 1990 are summarized in Table IX.

Comparative data with the two previous surveys are summarized in Table X from which the following comment and interpretation may be drawn:

(a) The increasing total area and precent of bottom covered reported is probably the result of improved survey techniques and finding growth areas not previously reported rather than an expansion of areal coverage of lake bottom

(b) The total lake biomass values show a significant variability but a trend to higher whole lake production in 1990. For stations that were directly comparable in 1986 and 1990, the biomass had doubled. It is believed that the 1990 figures are probably the best representation of the total standing crop biomass and that an increase in total production or seasonal variability has occurred.

(c) A doubling of the quantity of nitrogen contained by the *Dichotomosiphon* crop was estimated for 1990 over 1983, whereas the total phosphorus resource utilized remained much the same. As noted previously, no useful data are available from comparable stations in 1986 which might have clarified the true status of nitrogen and phosphorus composition of the plant tissues and use of these resources by the *Dichotomosiphon* crop in the lake. While an attempt was made to rationalize variability noted previously in tissue nutrient content through replicated analyses of samples from the same station, a significant variability remains. If the true tissue status is to be determined, a specific study using small samples of carefully, hand-washed plant material is required that is subjected to replicate analyses possibly by more than one accredited laboratory. None the less, the gross estimate provided for the lake suggests that in the order of 6 to 7t of phosphorus and 75 to 150t of nitrogen are incorporated and cycled annually through *Dichotomosiphon* biomass in Lake Simcoe.

(d) For metals analysed, iron is the most utilized element at 22 tonnes. Heavy metals were only measured in 1990. Values from about 10 to 110kg were estimated to be incorporated into plant materials. Considering the quantity of plant biomass and the small quantity of heavy metals found in the plant tissue, it would appear that they do not play a major role in mobilizing toxic metals into the ecosystem.

This could be confirmed by analyses of *Gammarus* populations living within and outside the *Dichotomosiphon* beds.

Table IX. Whole Lake Effect of *Dichotomosiphon Tuberosus* Production.

	1990
Total Area of Growth	67.2km^2
% of Lake Bottom Supporting Growth	9.3%
Total Wet Weight Biomass	27,350t
Total Dry Weight Biomass	5,846t
Total Ash-Free Dry Weight Biomass	3,391t
Total Biomass Nitrogen	143t
Total Biomass Phosphorus	5.96t
Total Fe	22.8t
Total Cd	10.8kg
Total Cr	27.4kg
Total Cu	47.2kg
Total Pb	108.7kg

Table X. Comparison by Year - Whole Lake Production.

	1983	1986	1990
Total Area km	56	58	67.2
% Covered	7.7	8	9.3
W.W. (t)	15,772	11,100	27,350
D.W. (t)	5,820	2,220	5,846
A.F.W.D. (t)	1,280	-	3,391
Total N (t)	75.9	-	143
Total P (t)	6.7	-	5.96
Total Fe (t)	21.5	-	22.8

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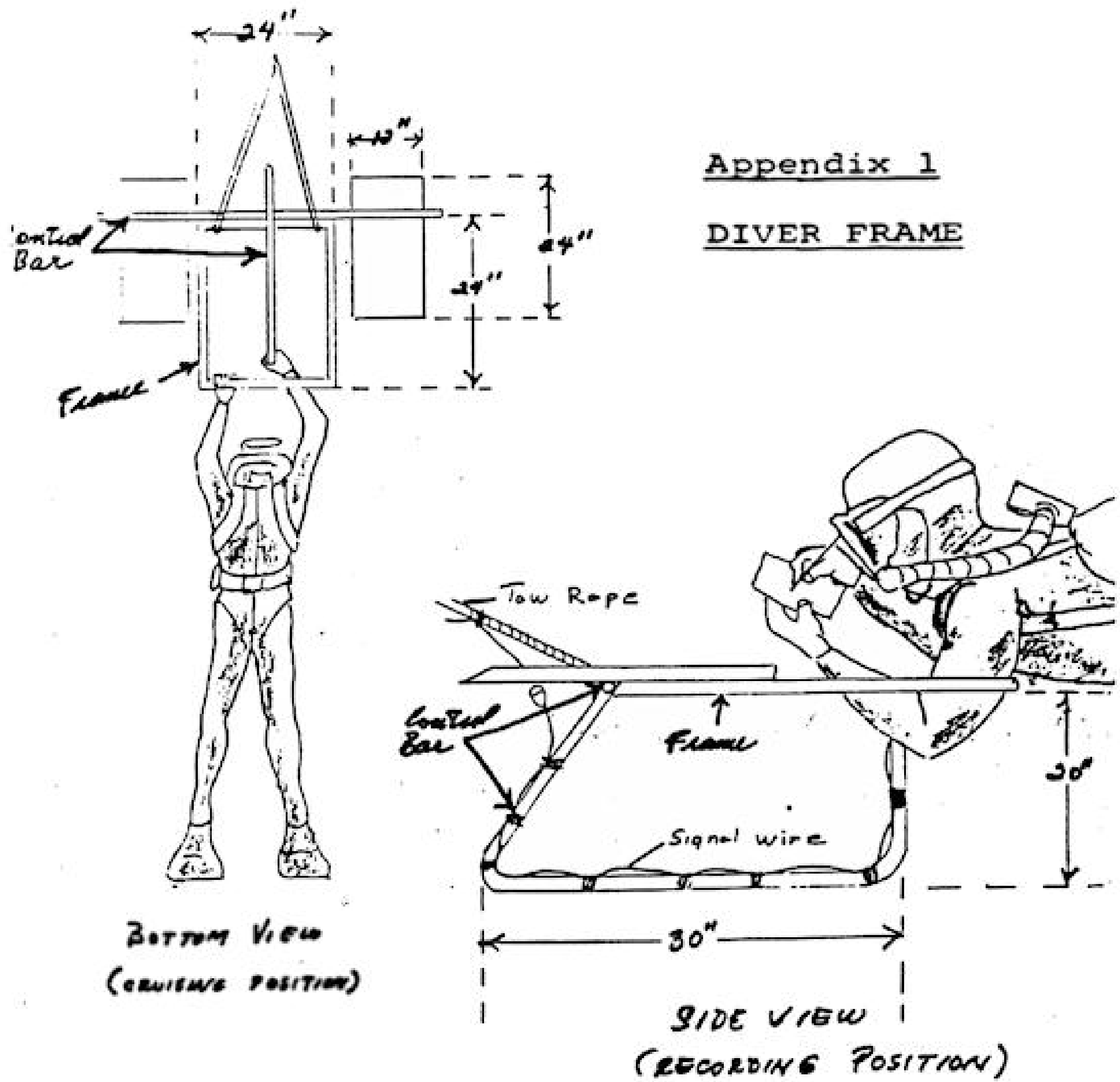
The ongoing studies of this interesting and possibly new species of alga to the lake is part of a steadily building body of scientific information directed to a more complete understanding of what is probably Canada's most valuable inland waterbody. These studies are directed by the Lake Simcoe Environmental Management Strategy committee which carries representation from the Ministries of the Environment and Natural Resources and the Lake Simcoe Region Conservation Authority.

We wish to thank the Committee for affording the opportunity to conduct the work to this time and particularly Mr. Ken Nicholls who provided technical direction to the study.

John H. Neil
President

Appendix 1. DIVER FRAME



Appendix 2. LORAN Coordinates for Transects Surveyed.

General Location	Transect No.	LORAN Coordinates		
		Start	Finish	
Willow Beach	A7	16014.2/59015.9	12.4	15.3
Jacksons Pt.-Due N.	A1	16005.6/59040.1	04.3	38.0
Mouth of Black R.	A2	16006.5/59049.0	01.8	48.4
Sibbald Pt. 323°	A3	16000.0/59059.6	15995.8/ 59053.5	
E. of Georgina Is. 86°	A4	15998.1/59072.4	95.9	77.8
E. of Georgina Is. 38°	A5	15992.0/59078.2	88.1	82.1
Georgina Is. W. 270°	A6	15983.2/59057.9	86.2	56.0
N. of Bald Shoal	B1	15984.5/59088.5	83.5	86.9
Pefferlaw Brook Bay	B2	15995.5/59091.9	91.9	94.3
Pefferlaw Ck.-Due N.	B3	15992.3/59102.9	89.3	01.3
Pefferlaw Ck.-Spot	B4	15985.7/59100.7	-	-
N. of Pefferlaw	B5	15986.6/59111.8	82.1	106.4
N. of Pefferlaw	B6	15975.8/59115.6	73.5	108.9
N. of Pefferlaw	B7	15969.5/59110.5	71.4	117.5
Big Shoal-Thorah Is.	B8	15974.4/59083.5	63.5	91.7
Trent Canal	C1	15942.3/59114.1	49.4	03.9
Thorah Is.-Dock	C2	15953.4/591.001	55.8	16.4
Thorah Is.- S. Point	C3	15959.8/59096.1	61.7	102.0
Thorah Is.- Eagle Pt.	C4	15956.7/59090.8	59.6	85.9
N. Thorah Is.	C5	15949.9/59093.6	48.2	93.2
N. of Mara Pt.	C6	15937.2/59103.5	38.5	99.7
N. of Mara Pt.	D1	15931.1/59100.9	31.9	94.6
N. of Gamebridge Pt.	D2	15924.9/59099.9	25.2	95.6
Lagoon City-Spot	D3	15915.8/59092.0	23.2	84.9
Lagoon City Bay	D4	15915.3/59081.2	13.6	88.6
McGinnis Pt.	D5	15916.0/59068.3	17.8	69.5
Cedarmont Pt.	E1	15927.0/59017.0	26.1	19.3
Moons Beach Pt.	E2	15922.7/59015.3	21.5	18.2
Grape Is.	E3	15917.2/59015.1	12.9	22.0
Cedar Pt.	E4	15909.3/59025.6	12.9	33.5
Big Bay Pt. Marina	F1	15989.0/58976.4	89.2	78.1
Big Bay Sandy Cove	F2	15999.5/58968.6	99.5	72.3

APPENDIX

MEMBERSHIP ON THE STEERING COMMITTEE FOR THE LAKE SIMCOE ENVIRONMENTAL MANAGEMENT STRATEGY IMPLEMENTATION PROGRAM

D. Marquis, Lake Simcoe Region Conservation Authority (Chairman)

A. Morton, Lake Simcoe Region Conservation Authority (past member)

J. Barker, Maple District, Ministry of Natural Resources

E. Cavanagh, York County, Ministry of Agriculture and Food

R. DesJardine, Central Region, Ministry of Natural Resources (past member)

J. Kinkead, Watershed Management Branch, Ministry of the Environment (past member)

J. Merritt, Director - Central Region, Ministry of the Environment

P. Miller, Watershed Management Branch, Ministry of the Environment

B. Noels, Lake Simcoe Region Conservation Authority (Secretary)

APPENDIX

MEMBERSHIP ON THE TECHNICAL COMMITTEE FOR THE LAKE SIMCOE ENVIRONMENTAL MANAGEMENT STRATEGY IMPLEMENTATION PROGRAM

B. Noels, Lake Simcoe Region Conservation Authority (Chairman)

J. Beaver, Central Region, Ministry of the Environment

R. DesJardine, Central Region, Ministry of Natural Resources (past member)

J. Dobell, Huronia District, Ministry of Natural Resources

D. Green, Resources Management Branch, Ministry of Agriculture and Food (past member)

B. Kemp, Lake Simcoe Region Conservation Authority

J. Kinkead, Watershed Management Section, Ministry of the Environment (past member)

R. MacGregor, Central Region, Ministry of Natural Resources (past member)

N. Moore, Victoria-Haliburton County, Ministry of Agriculture and Food

K. Nicholls, Water Resources Branch, Ministry of the Environment

B. Peterkin, Central Region, Ministry of Natural Resources

T. Rance, Maple District, Ministry of Natural Resources

B. Stone, Northumberland County, Ministry of Agriculture and Food

M. Walters, Lake Simcoe Region Conservation Authority

C. Willox, Lake Simcoe Fisheries Assessment Unit, Ministry of Natural Resources

K. Willson, Watershed Management Section, Ministry of the Environment

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