

REDUCTION OF CLADOPHORA BIOMASS AND TISSUE

PHOSPHORUS IN LAKE ONTARIO

1972-1983

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MANAGEMENT PERSPECTIVE

Cladophora, a nuisance filamentous green alga, grows in the nearshore zone of the Great Lakes. Accumulations of decaying Cladophora cause aesthetically unpleasant shorelines and have been implicated in drinking water taste and odor events. Phosphorus control programs were initiated in Lake Ontario in the early 70's to control phytoplankton growth in the open lake but may have also affected Cladophora growth in the nearshore zone. The Ontario Ministry of Environment sampled seven sites for Cladophora biomass and tissue chemistry in 1972 which is when phosphorus concentrations had peaked. We sampled the same seven sites in 1982 and 1983 to determine if the phosphorus control programs had affected Cladophora. An assessment of Cladophora growth in 1983 is particularly valuable because growth conditions are not likely to change in the near future.

The lakewide average dry weight decreased by 58% and the lakewide average tissue phosphorus decreased by 59% from 1972 to 1983. Cladophora growth was not limited by phosphorus in 1972 but was limited in 1983. Dramatic decreases in tissue phosphorus between 1972 and 83 were observed at sites influenced by local nutrient sources, whereas at Point Petre which represents open lake nutrient conditions, the tissue phosphorus had declined but not as dramatically. The greater improvement in the nearshore water quality relative to the offshore quality is to be expected because the phosphorus control programs have involved reductions of onshore loadings. Modelling of Cladophora growth using 1983 data indicates that greater potential for Cladophora growth exists in the western end of L. Ontario compared to the eastern remote sites. The greater growth potential in the west is mainly a function of higher phosphate concentrations.

PERSPECTIVE-GESTION

La Cladophora, une algue verte filamenteuse, croît dans la zone littorale des Grands Lacs. Des accumulations de Cladophora en décomposition portent atteinte à l'esthétique des côtes et influent négativement sur le goût et l'odeur de l'eau potable. Au début des années 70, des programmes de contrôle du phosphore ont été entrepris dans le lac Ontario pour contrôler la croissance du phytoplancton dans le lac ouvert, mais ils ont pu influencer également sur la croissance de la Cladophora dans la zone littorale. Le ministère de l'Environnement de l'Ontario a échantillonné sept sites pour déterminer la biomasse et la composition chimique des tissus de la Cladophora en 1972, date à laquelle les concentrations de phosphore avaient grimpées. Nous avons échantillonné les sept mêmes sites en 1982 et en 1983 pour déterminer si les programmes de contrôle du phosphore avaient influé sur la Cladophora. L'évaluation de la croissance de la Cladophora en 1983 s'est avérée plutôt utile car il est peu probable que les conditions de croissance changent dans un avenir rapproché.

Le poids moyen sec a diminué de 58 p. 100 et la concentration tissulaire moyenne de phosphore, de 59 p. 100 dans l'ensemble du lac, de 1972 à 1983. La croissance de la Cladophora n'a pas été ralentie par le phosphore en 1972, mais l'a été en 1983. Entre 1972 et 1983, nous avons observé aux sites que la concentration tissulaire de phosphore avait diminué radicalement à cause des sources locales d'éléments nutritifs, tandis qu'à Pointe Petre, réunissant les conditions nutritives d'un lac ouvert, elle avait baissé, mais pas de façon aussi prononcée. Nous prévoyons une nette amélioration de la qualité de l'eau dans la zone littorale comparativement à la qualité de l'eau dans le lac ouvert, car les programmes de contrôle du phosphore contribuent à réduire les charges côtières. Selon le modèle de croissance de la Cladophora constitué à l'aide des données de 1983, il est plus probable que la Cladophora croisse dans la partie ouest du lac Ontario que dans les sites éloignés à l'est. Si la possibilité de croissance est plus grande à l'ouest, c'est principalement en raison des plus fortes concentrations de phosphate qui s'y trouvent.

ABSTRACT

Cladophora biomass and tissue phosphorus concentrations at seven sites in Lake Ontario have decreased from 1972 to 1983 in response to phosphorus control programs introduced in the early 70's. The lakewide average dry weight was 205.8, 80.0 and 85.0 grams per square meter for 1972, 1982 and 1983 respectively. The 1972 lakewide average tissue phosphorus was 0.49%; the 1982 lakewide average was 0.26% P and the 1983 lakewide average was 0.20% P on an ash-free dry weight basis (AFDW). The 1972 tissue phosphorus concentrations did not limit growth, but tissue phosphorus had begun to limit growth in 1983. Predicted net production for the six week sampling period in 1983 was 1.7 times greater in the western end of the lake compared to the remote site in the eastern end of Lake Ontario due to higher phosphate concentrations in the west.

RÉSUMÉ

La biomasse de la Cladophora et la concentration tissulaire de phosphore ont diminuées de 1972 à 1983 à la suite des programmes de contrôle du phosphore entrepris au début des années 70. Le poids sec moyen dans l'ensemble du lac correspondait à 205,8, 80,0 et 85,0 grammes le mètre carré en 1972, en 1982 et en 1983 respectivement. En 1972, les concentrations tissulaires moyennes de phosphore dans l'ensemble du lac étaient de 0,49 p. 100, en 1982, elles étaient de 0,26 p. 100 et en 1983, de 0,20 p. 100, compte tenu du poids sec décalcifié (PSD). Les concentrations tissulaires de phosphore enregistrées en 1972 n'avaient pas ralenti la croissance de la Cladophora, mais en 1983, elles ont commencé à le faire. La production nette prévue pour les six semaines d'échantillonnage, en 1983, était 1,7 fois plus élevée dans la partie ouest du lac Ontario que dans les sites éloignés à l'est, les concentrations de phosphate étant plus fortes à l'ouest.

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INTRODUCTION

Since the mid 1950's extensive blooms of the filamentous alga, Cladophora, have created problems along the Lake Ontario shoreline. Large odoriferous masses of decaying Cladophora are frequently washed up onto shore by storm events during the summer growing season. The decaying Cladophora is aesthetically unpleasant for shoreline activities and shoreline property owners and has been implicated in taste and odor events in drinking water supplies (Boone, 1984). Cladophora growth is regulated by a combination of environmental factors including light, temperature and phosphate availability (Canale and Auer, 1982). Cladophora grows attached to rocky substrates, so the extensive bedrock shelf in Lake Ontario from Burlington to Toronto can create massive accumulations of Cladophora biomass. Phosphorus inputs into Lake Ontario have been controlled and soluble reactive phosphate and total phosphorus levels have dropped in the open lake since 1973 to levels approaching the desired target concentrations in 1983 (Dobson, 1984).

Cladophora biomass and tissue phosphorus were sampled at seven sites in L. Ontario in 1972 when phosphorus concentrations in L. Ontario were approaching their maximum. The Ontario Ministry of Environment conducted the survey as part of the International Field Year for the Great Lakes (IFYGL). In order to determine if the phosphorus control programs have affected the Cladophora standing crop or tissue phosphorus concentrations and hence growth, Environment Canada contracted Limnos Ltd. to repeat one of the three sample series conducted in 1972 in 1982 and conduct three sample series in 1983. Water quality data was also collected to model the current growth potential of Cladophora in Lake Ontario.

METHODS

The seven sites chosen in 1972 were Oakville, Whitby, Cobourg, Presqu'ile, Point Petre, Bath and Emeric Point. The 1972 stations were sampled on three occasions, once in each of June, July and August. The 1982 survey was performed in July to determine if significant changes had occurred over the ten year period. Based on the 1982 survey, a decision was made to survey on three occasions in 1983 but to change the sampling times to mid-June, late June and mid-July with the hope of recording the seasonal peak biomass. Sampling was not conducted in August 1983

because the lake is normally too warm and the Cladophora beds have died and sloughed off by August. Figure 1 illustrates the location of the sites within the Lake Ontario basin.

In order to ensure data consistent with previous studies conducted in Lakes Erie and Ontario, sampling and analytical procedures for Cladophora monitoring established for the IJC Surveillance Program in Lake Erie for the 1979 season and described by Carnes and Millner (1980) were adopted. Cladophora sampling was conducted by SCUBA at four depths - 0.5, 1.5, 3.0 and 5.0 metres at each site. At each depth three replicate 0.25 square metre quadrats were cropped by diver and collected on the surface vessel by a gasoline powered venturi pump (Limnos, 1981). Collected algae were measured for weight and volume and frozen pending analysis. Biomass samples were analyzed for % water (dry weight), loss on ignition (LOI) and total tissue phosphorus. The loss on ignition was used to correct the tissue phosphorus concentration to an ash-free dry weight basis (AFDW). The analyses for phosphorus were conducted by the Ontario Ministry of Environment's Rexdale Laboratory.

Water samples for soluble reactive phosphate and total phosphorus were taken at the shore, 1.5 and 5.0 metre depths and offshore (twice the offshore distance of the 5.0 m site). Water samples for SRP analyses were filtered in the field using acid

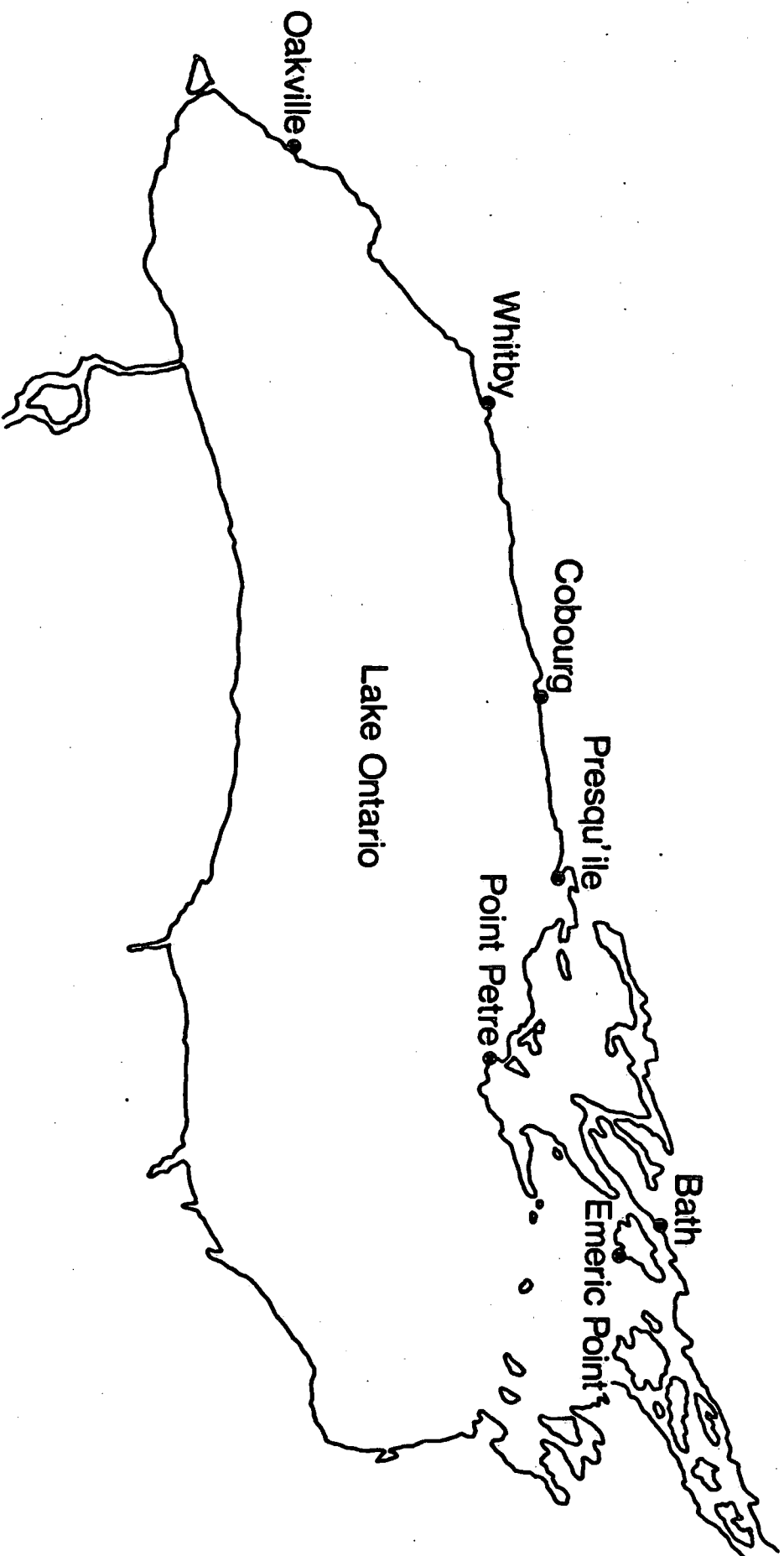


Figure 1 LAKE ONTARIO LAKEWIDE SURVEY

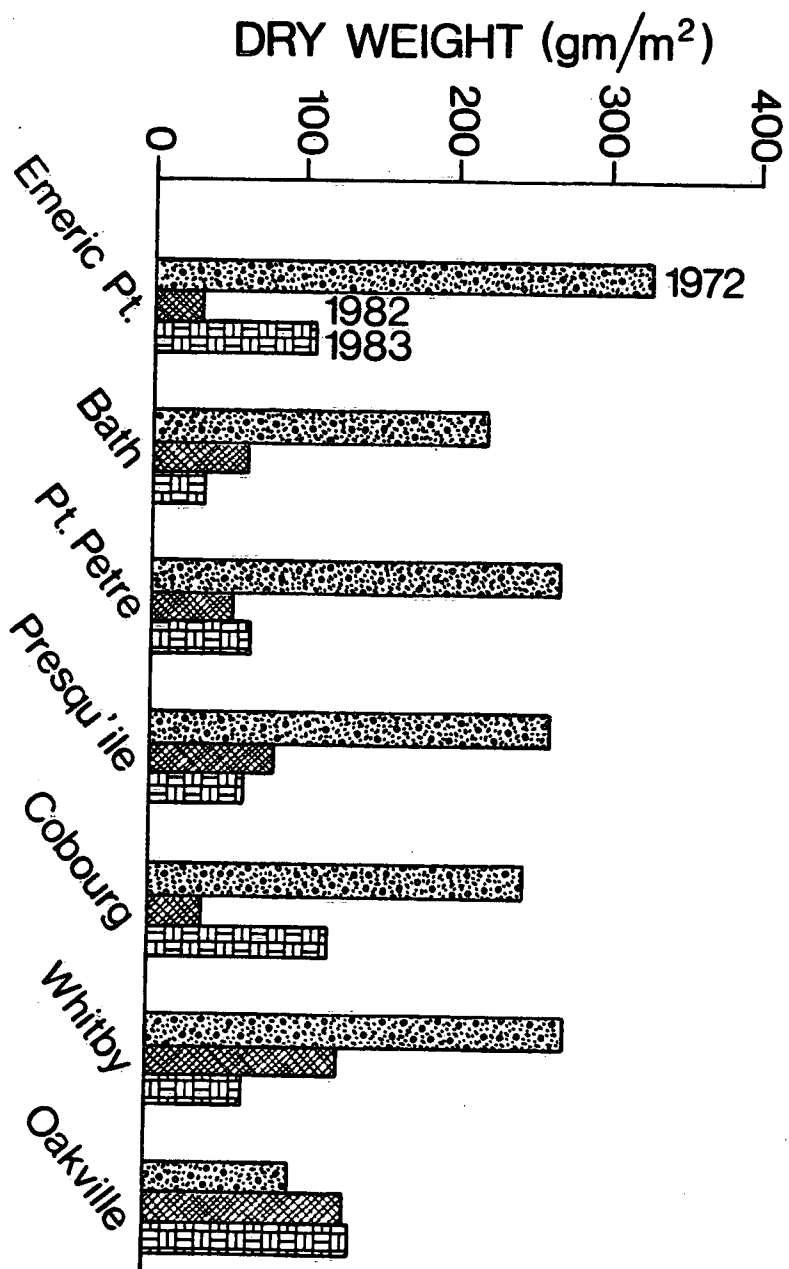
rinsed 0.45u millipore filters and stored on ice in the field and then refrigerated until analysis. Water samples for total phosphorus were preserved with 5% sulphuric acid and stored on ice in the field and then refrigerated until analysis.

Secchi depths and water temperatures were measured at the seven sites. The secchi depth and water temperature along with the SRP data were used to simulate Cladophora growth for the six-week period in 1983 using a Cladophora simulation model developed by Scott Painter on the basis of the publications of Auer and Canale (1982). Tissue phosphorus and net production were predicted with the model. The predicted tissue phosphorus was compared to the actual tissue phosphorus and the six week net production response was used to compare the stations to one another.

RESULTS

The stations' standing biomasses as a yearly average for all depths are plotted in Figure 2. According to the collected standing crop data, with the exception of Oakville, a substantial reduction in standing biomass has occurred between 1972 and 1982/83. Standing dry weight, averaged on a lakewide basis, was 205.8, 80.0 and 85.9 g per square meter for 1972, 1982 and 1983 respectively, or in other words a 58% decrease in biomass has occurred between 1972 and 1983. The 1982 and 1983

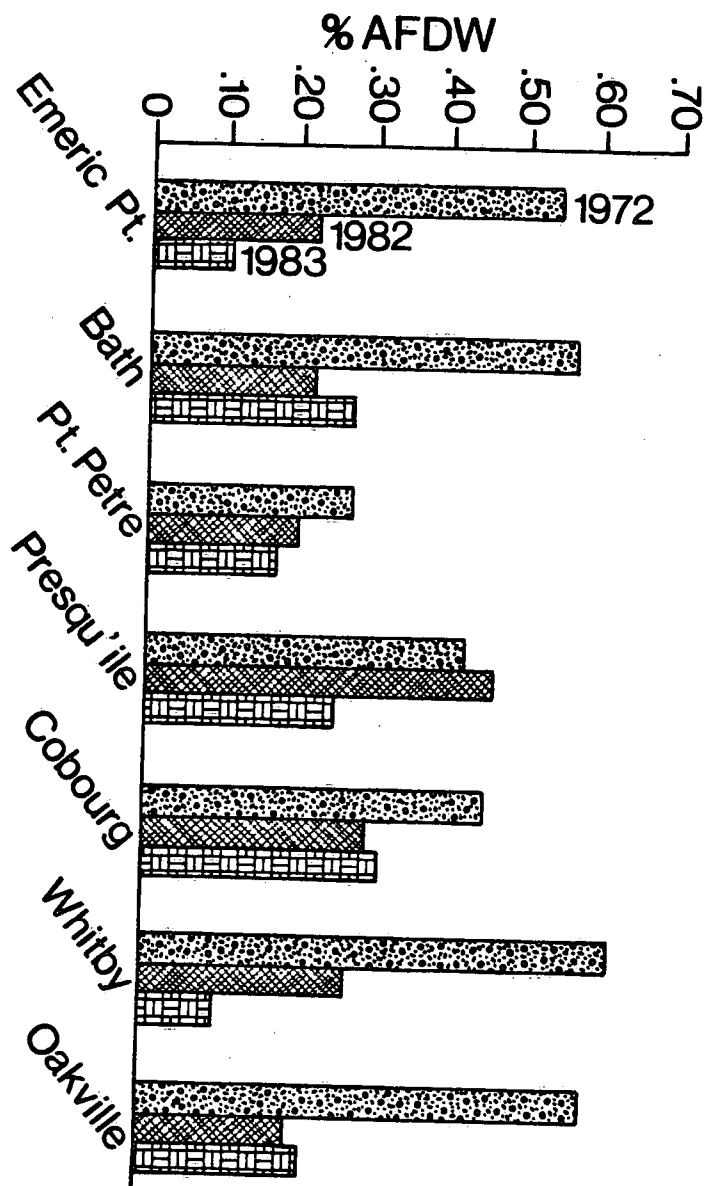
Figure 2 BIOMASS 1972, 1982 & 1983



data compare well even though the 1982 data is based on only one sampling date at the seven sites. Comparison of the standing crop between stations indicates that no definite geographical trends for Cladophora biomass along the Lake Ontario shoreline was apparent. The standing crop of Cladophora present at any one time is dependent on growth rate, of course, but storm events can completely scour the bottom so interpretation of the data must be tempered with an understanding of the factors controlling standing crop. A much more reliable measurement to use for yearly and station to station comparisons is tissue phosphorus.

Seasonal averages of tissue phosphorus are presented in Figure 3. The tissue phosphorus content is expressed on an ash-free dry weight basis to account for seasonal and year to year variations in ash content. Tissue phosphorus levels have been substantially reduced between 1972 and 1983. At all locations the 1983 tissue levels were less than the 1972 concentrations. The 1972 lakewide average tissue phosphorus was 0.49% (AFDW) and the 1983 lakewide average was 0.20 % P(AFDW) which is a 59% reduction in tissue phosphorus over the eleven year interval. With the exception of the Presqu'ile site, the 1982 data is very comparable to the 1983 levels, with a lakewide average of 0.26% P(AFDW). The Point Petre site in 1972 had the lowest tissue phosphorus concentration because the site is quite

Figure 3 TISSUE PHOSPHORUS 1972, 1982 & 1983



remote and is probably responding to open Lake Ontario nutrient conditions. The other locations are nearshore sites influenced by onshore nutrient loading which elevates the nearshore phosphate concentrations relative to the open lake concentrations. The Whitby and Oakville sites, of course, are affected by the large centres of population from Oshawa to Hamilton. The Bath site is affected by a local sewage treatment plant and the Emeric Point site is affected by the outflow from the Bay of Quinte. The Point Petre Cladophora tissue phosphorus in 1982/83 had decreased the least of all the sites relative to the tissue phosphorus of the Cladophora at the site in 1972. All the other locations had dramatic reductions in the tissue phosphorus, indicating that the nearshore zone of Lake Ontario has improved much more in a relative sense than the open lake. The relative improvement in the nearshore zone is to be expected because the phosphorus control programs have involved reductions of onshore loadings and the differences between the nearshore quality and the offshore quality are a function of the dispersion and dilution of the onshore loadings.

The 1972 and 1983 tissue phosphorus concentrations on a dry weight basis were plotted on the Droop curve relationship between net specific growth and tissue phosphorus as reported by Auer and Canale (1982). Figure 4 illustrates the station data as well as the lakewide averages for 1972 and 1983. The 1972 tissue

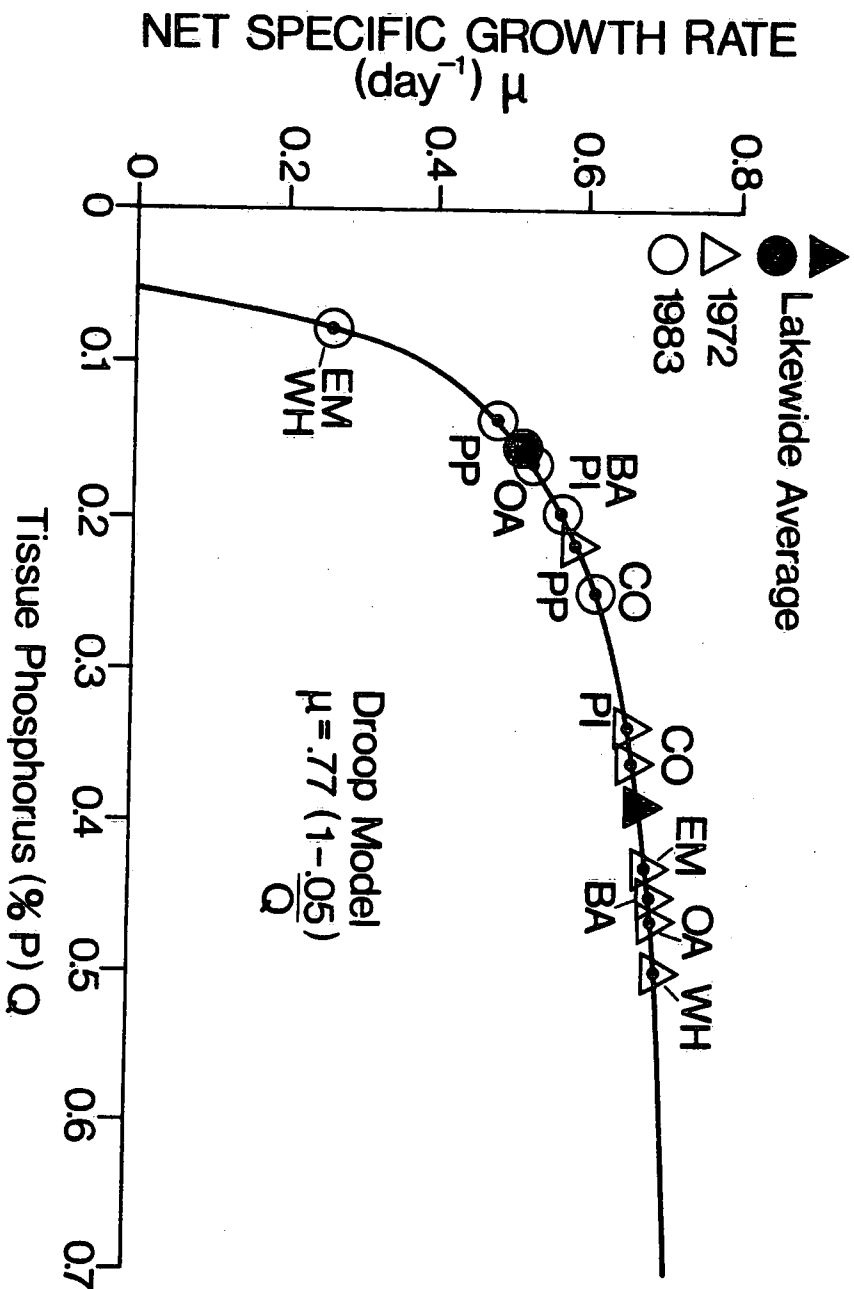


Figure 4 1972 & 1983 TISSUE PHOSPHORUS IN RELATION TO AUER & CANALE NUTRIENT - GROWTH MODEL
(Droop curve after Auer and Canale, 1982)

phosphorus data were situated on the plateau of the curve indicating that phosphorus was not limiting growth of Cladophora in the early 70's. The 1983 tissue phosphorus data are all located on the descending portion of the curve indicating that phosphorus is limiting growth to a greater or lesser extent depending of the station.

Cladophora net production and tissue phosphorus were simulated for a six week period using Secchi depth, temperature and soluble reactive phosphorus data for each station. The tissue phosphorus predictions agreed very well with the observed tissue phosphorus. Net production for the six weeks was averaged to give a daily average net production for each site. The average net production for each site was then compared to the average net production at Point Petre, our most remote site. Figure 5 presents the comparisons of net production, with the circle diameter for each site being relative to the circle diameter for Point Petre. A definite geographical trend is apparent for the predicted net production which takes into account all significant environmental variables important for Cladophora growth. Point Petre and Emeric Point had the least potential for growth and the potential for growth increased towards the western, more populated, end of Lake Ontario. The Oakville site was predicted to have 1.7 times more growth than the Point Petre site. The trend of increased growth potential from east to west is mainly a function of soluble reactive phosphorus which increased from average values of 1.8-2.7 $\mu\text{g}/\ell$ in the east to 5.8-7.0 $\mu\text{g}/\ell$ in the west.

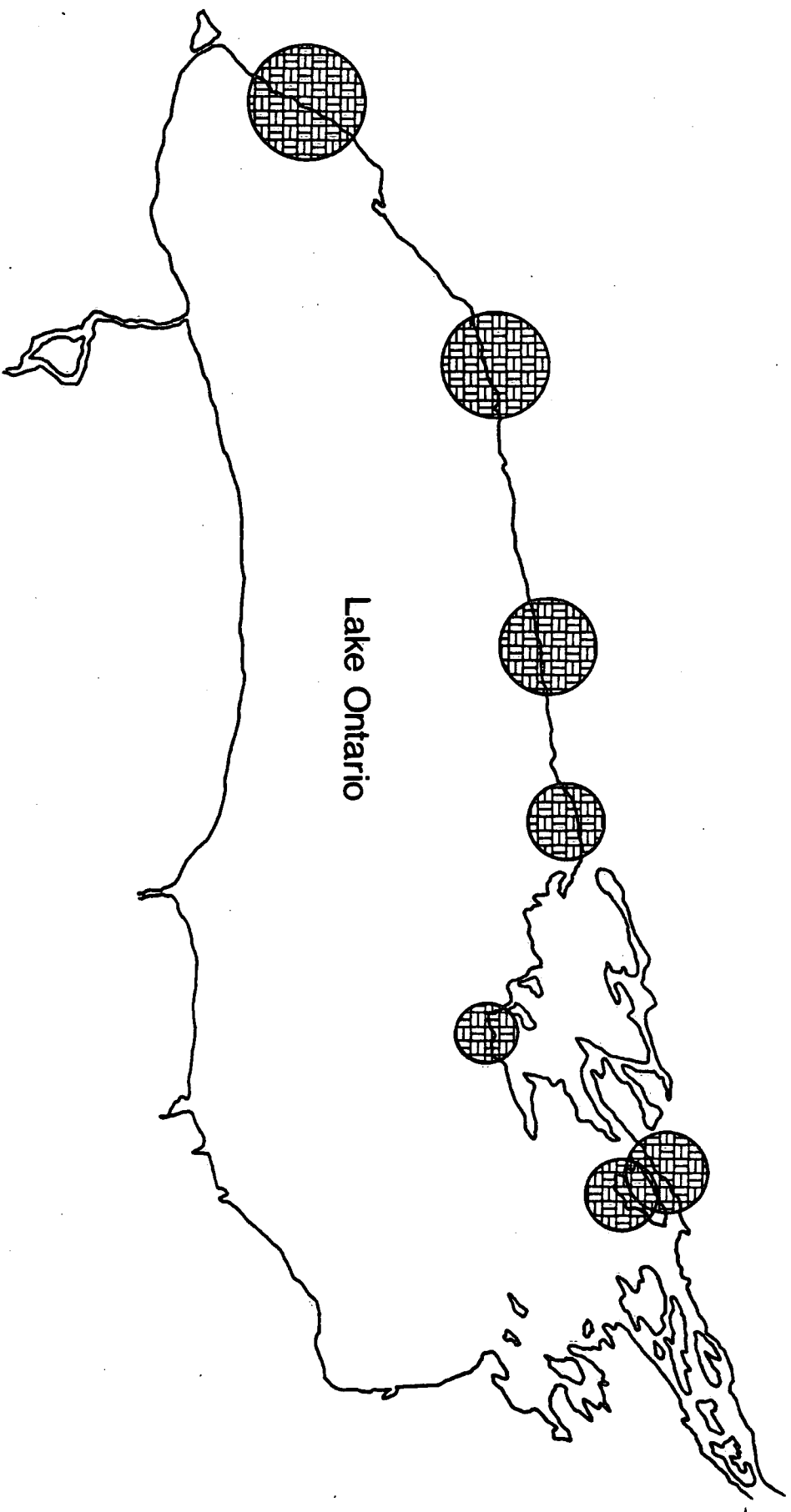


Figure 5 PREDICTED RELATIVE GROWTH POTENTIAL

CONCLUSIONS

Comparison of biomass and tissue phosphorus of Cladophora collected from seven sites in Lake Ontario in 1972, when lake phosphorus levels were highest, and in 1982, 83, when lake phosphorus levels were approaching the target concentrations, indicate that substantial reductions in Cladophora biomass and tissue phosphorus had occurred. The 1983 lakewide tissue phosphorus concentrations are beginning to limit growth. Further reductions in phosphorus loading into Lake Ontario could significantly reduce Cladophora populations. The nearshore zone in the western end of Lake Ontario is subject to higher nutrient fluxes than the more remote eastern end simply because of the proximity to the onshore loading sources. The large areas of suitable bedrock substrate in the Burlington to Toronto area plus the relative enrichment of the nearshore zone compared to open lake conditions may mean that nuisance accumulations of Cladophora on the shoreline may still occur depending on the frequency of storm events even though the growth rate of Cladophora on an areal basis is limited by phosphorus.

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