SESTON CARBON, NITROGEN, PHOSPHORUS AND PHYTOPLANKTON FROM EIGHT ONTARIO LAKES

research report w46

1973

Ontario

Ministry
of the
Environment

SESTON CARBON, NITROGEN, PHOSPHORUS AND PHYTOPLANKTON FROM EIGHT SOUTHERN ONTARIO LAKES

by

A. E. Christie, Ph.D.

July, 1973

Research Report W46

Research Branch

Ministry of the Environment
135 St. Clair Avenue West
Toronto, Ontario
M4V 1P5

ABSTRACT

Seston samples from eight lakes lying within the Trent River Drainage Basin, located in central Ontario, were characterized with respect to three nitrogen fractions, three phosphorus fractions, organic carbon, phytoplankton content and chlorophyll a.

Significant direct positive relationships were found to exist between each of the nutrient parameters and the algal biomass. Non-labile nitrogen or phosphorus to biomass ratios - mg.N_3 :cm^3 algae - 7.3:1; mg P_3:cm^3 algae - 0.6:1; mg N_3: mg chlorophyll a - 6.7:1; mg P_3: mg chlorophyll a - 0.6:1 - showed close agreement with similar ratios obtained with samples from a previous study in the Bay of Quinte.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Phosphorus and nitrogen requirements of phytoplankton both in natural systems and laboratory cultures have been assessed on the basis of chemical analyses of the associated suspended solids or seston. Inasmuch as algae can accumulate phosphorus, and perhaps nitrogen, in excess of their immediate needs, this approach may yield misleading information in estimating the critical nutrient requirements of these organisms.

A technique described by Fitzgerald and Nelson (1966) to characterize the essential phosphorus content of algae was applied to samples of seston obtained during a study of the Bay of Quinte (Christie, 1972b). Results from the Quinte investigation illustrated a close agreement when compared to the various nutrient:biomass ratios as reported by several authors (Mullin *et al*, 1962; Strickland, 1960; Vollenweider, 1970).

Seston samples analyzed in the following investigation, obtained during an examination of nutrient-phytoplankton relationships of eight lakes lying within the Trent River Drainage Basin (Christie, 1968), were assayed to determine whether relationships obtained with materials from the Bay of Quinte also exist in other freshwater environs of Ontario.

MATERIALS AND METHODS

The suspended solids or seston materials analyzed in this study are identical to the materials employed to characterize the standing crops of phytoplankton of the trophogenic waters of eight lakes which lie in the Trent River Drainage Basin of Southern Ontario as reported by Christie, (1968).

Initial concentration of this material for phytoplankton enumeration, previously described in the above report and more recently by Christie, (1972a) involved treatment of the raw water with mercuric chloride followed by concentration using a Sedgwick-Rafter sand filter funnel (acid washed sand). Raw water volumes of 1000 ml or 500 ml were concentrated to a final volume of 25 ml. Procedures involved in the preparation of a 5.0 ml aliquot of seston concentrate for carbon, nitrogen and phosphorus analyses have been described previously in some detail (Christie, 1972b).

In this report the carbon, nitrogen and phosphorus content of untreated aliquots of concentrate are indicated as Cp, N_1 and P_1 respectively. The quantities of nitrogen and phosphorus associated with the suspended materials after centrifugation and distilled water rinsing are indicated by N_2 and P_2. Parameters N_3 and P_3 represent the nitrogen and phosphorus quantities of concentrates after isolation by centrifugation, resuspension in a nitrogen-phosphorus free mineral media followed by a one hour boiling water bath treatment (Fitzgerald and Nelson, 1966).

Statistical analyses of the data followed procedures outlined by Snedecor and Cochrane (1957).

Duplication of analyses of the nitrogen and phosphorus content of concentrates of 45 samples (N_1, P_1) indicated no significant difference to exist between replicates at the 95 percent level of confidence.

RESULTS

PHYTOPLANKTON: QUANTITY AND COMPOSITION

The phytoplankton content of water samples representing the trophogenic zone of each of eight lakes which lie within the Trent River Drainage Basin - Kushog (K), Twelve-mile (T) , Balsam (B) , Gull (G), Sturgeon (S) , Buckhorn (Bu), Clear (C), Rice (R) - previously reported in terms of areal standard units (Christie, 1968), are displayed in Figure 1 on the basis of parts per million by volume ($cm^3.m^{-3}$) and chlorophyll a ($mg.m^3$) uncorrected with respect to phaeophytin content.

In Figure 2 the composition of the various standing crops of phytoplankton, based on $cm^3 .m^{-3}$,indicate the predominant presence of Bacillariophyta, made up primarily of such forms as *Asterionella, Fragilaria, Melosira, Synedra* and *Tabellaria*. A detailed listing of the phytoplankton noted in samples from each lake have been reported elsewhere (Christie, 1968).

The relationship between the two biomass parameters was examined using all the chlorophyll data (63 observations) and the algal biomass values of equivalent samples. This analyses yielded a positive linear relationship significant at the 99.5 percent level with a dependent variable sample standard error ($S\bar{y}.x$) of 0.3516: Chlorophyll a ($mg.m^3$) = 0.1330 (10) + 0.6562 ($cm^3.m^{-3}$).

SESTON NUTRIENTS AND PHYTOPLANKTON

The nutrient contents of seston samples from all the lakes after various treatments - phosphorus (P_1, P_2, P_3), nitrogen (N_1, N_2, N_3), and carbon (Cp) - were compared to corresponding estimates of the standing crops of phytoplankton expressed as parts per million by volume ($cm^3.m^{-3}$) or as chlorophyll a ($mg.m^{-3}$) (Figures 3, 4, 5). Statistical testing between these data in each instance yielded a direct positive relationship with all but two cases being significant at the 99.5 percent level (P = 0.005).

The mean, range and number of observations associated with each nutrient fraction are presented in Table II as are also the two biomass parameters.

From substitution of the biomass mean value in each equation, a corresponding dependent variable value was determined. The various nutrient quantity biomass ratios displayed in Table III were calculated by dividing the estimated nutrient value by the mean of the biomass parameter.

DISCUSSION AND CONCLUSION

Relationships between phytoplankton development and their carbon, nitrogen and phosphorus requirements have been examined by determining the nutrient contents of seston samples both from natural environs and laboratory cultures. Based on the latter method, the minimum phosphorus requirement for several species of phytoplankton has been reported to range from 0.2 - 0.6 mg:cm^3. (Vollenweider, 1970). Carbon:biomass ratios according to Mullin *et al* (1962) were found to vary from 30 - 250 mg C:cm^3, being dependent on cell size. Suggested ratios between seston phosphorus, nitrogen, carbon and chlorophyll a (wt:wt) are 0.75 mg P, 7 mg N, 30 mg C per mg chlorophyll a (Strickland, 1960).

Of the various nutrient:chlorophyll a ratios obtained in this study (Table II), as determined from the regression equations based on data of Figures 3, 4, 5, the ratios mg P_3: mg chlorophyll a and mg N_3:chlorophyll a with values of 0.6:1 and 6.7:1 are very similar to those suggested by Strickland (1960) whereas the observed carbon:chlorophyll a ratio - 214 mg C: mg chlorophyll a - is about seven fold greater.

On the other hand, the ratio of 226 mg Cp:cm^3 does fall within the range reported by Mullin *et al* (1962) as does the ratio between the most tightly bound seston phosphorus fraction versus biomass (0.6 mg P_3:cm^3) to the range of values for the minimum phosphorus requirements per unit biomass volume, 0.2 - 0.6 mg P:cm^3 (Vollenweider, 1970). The phosphorus associated with the P_3 fraction is, therefore, considered to approximate the essential phosphorus requirement of the associated phytoplankton biomass. While no comparative data are available with respect to the minimum nitrogen requirement per unit volume of algal biomass, the closeness of the

observed ratio N_3:chlorophyll a to the ratio suggested by Strickland (1960) would suggest that the N_3 nitrogen may represent the minimum nitrogen requirement per unit biomass volume.

Relationships between the nutrient contents of the seston and associated phytoplankton of samples from the Bay of Quinte have been reported previously (Christie, 1972b). Collection and handling of samples were identical in both the Quinte study and the present investigation.

From the results of the Bay of Quinte study, positive linear relationships were found to occur between the data representing the various seston nutrient fractions versus the phytoplankton biomass, all being significant at the 99.5 percent level. In this study data representing similar fractionation of the seston nutrients when compared to associated biomass parameters also yielded a positive linear relationship in each case although some variation in the degree of significance is evident. (Figures 3, 4).

In Table III, nutrient biomass ratios calculated from the appropriate regression equations of both the present and the Quinte study are presented for comparative purposes. Although, for example, the total seston phosphorus to biomass ratios (P_1:biomass) show some variation, close agreement is evident between the ratios representing the most tightly bound phosphorus moiety versus biomass (P_3:biomass). A similar type of relationship is evident with respect to the N_1:biomass to N_3:biomass ratios from the two studies.

The values displaying the widest degree of variation between the two investigations are the carbon:biomass ratios. Perhaps, considering the diverse nature of the phytoplankton populations involved, in the present investigation (Figure 2) as compared to phytoplankton populations of the Bay of Quinte, which consisted predominantly of Bacillariophyta and Cyanophyta (Christie, 1972b), this type of variation should not be considered surprising. Both carbon:cm^3 values do fall, however, within the range of 30 - 250 mg C:cm^3 noted by Mullin *et al* (1962).

The close agreement of the results of this study with various published nutrient:biomass ratios and with the findings obtained from the Bay of Quinte investigation indicate that such relationships are more than just a local phenomenon of one particular Ontario freshwater environ.

Figure 1. Phytoplankton standing crops ($cm^3.m^{-3}$) and chlorophyll a concentrations ($mg.m^{-3}$) of the trophogenic zone of eight lakes of the Trent River Drainage Basin - Kushog (K), Twelvemile (T). Gull (G), Balsam (B), Sturgeon (5), Buckhorn (Bu), Clear (C), Rice (R).

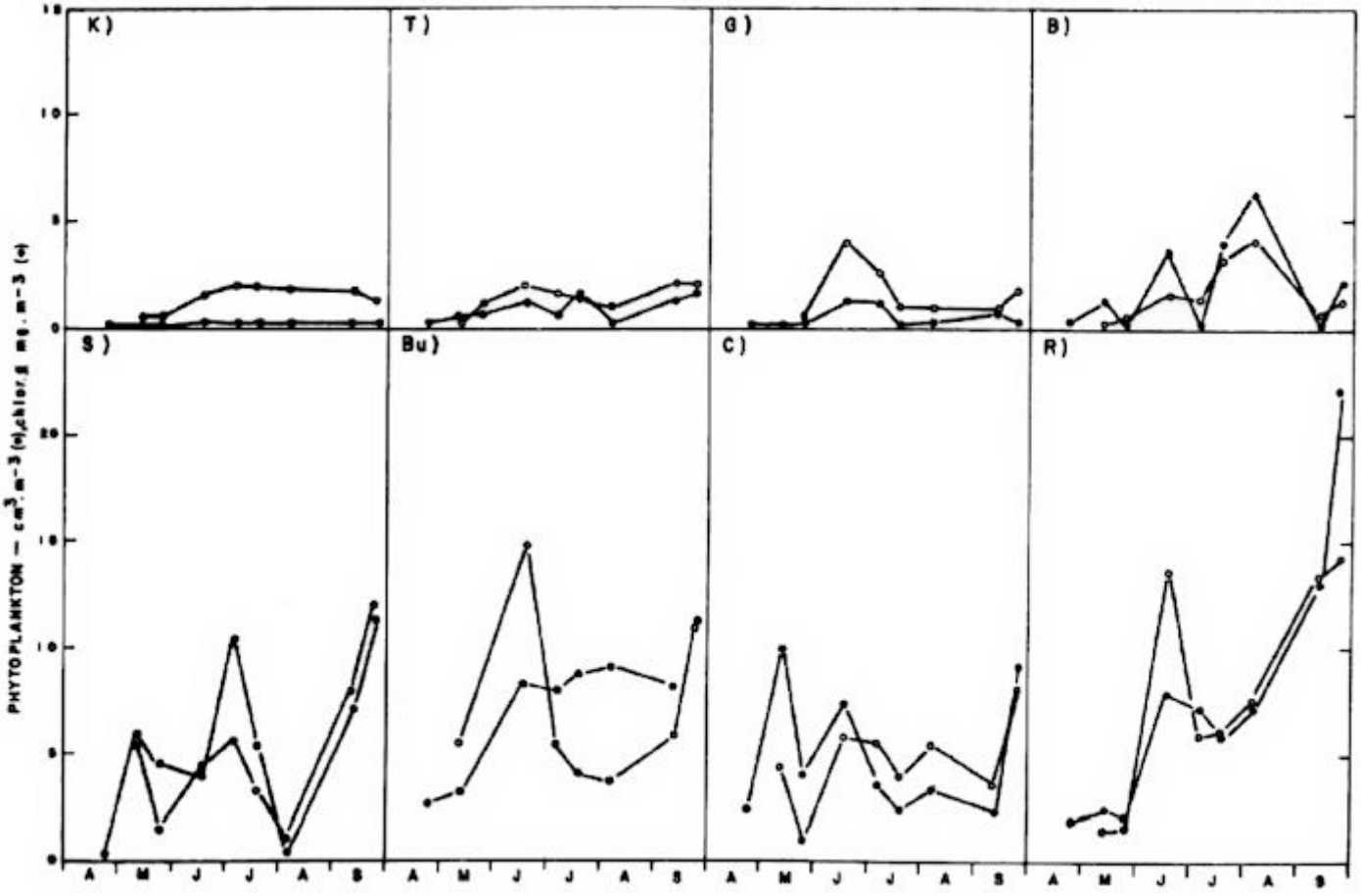

Figure 2. The percentage composition of the standing crops of phytoplankton of the trophogenic zone associated with each lake based on $cm^3 . m^{-3}$.

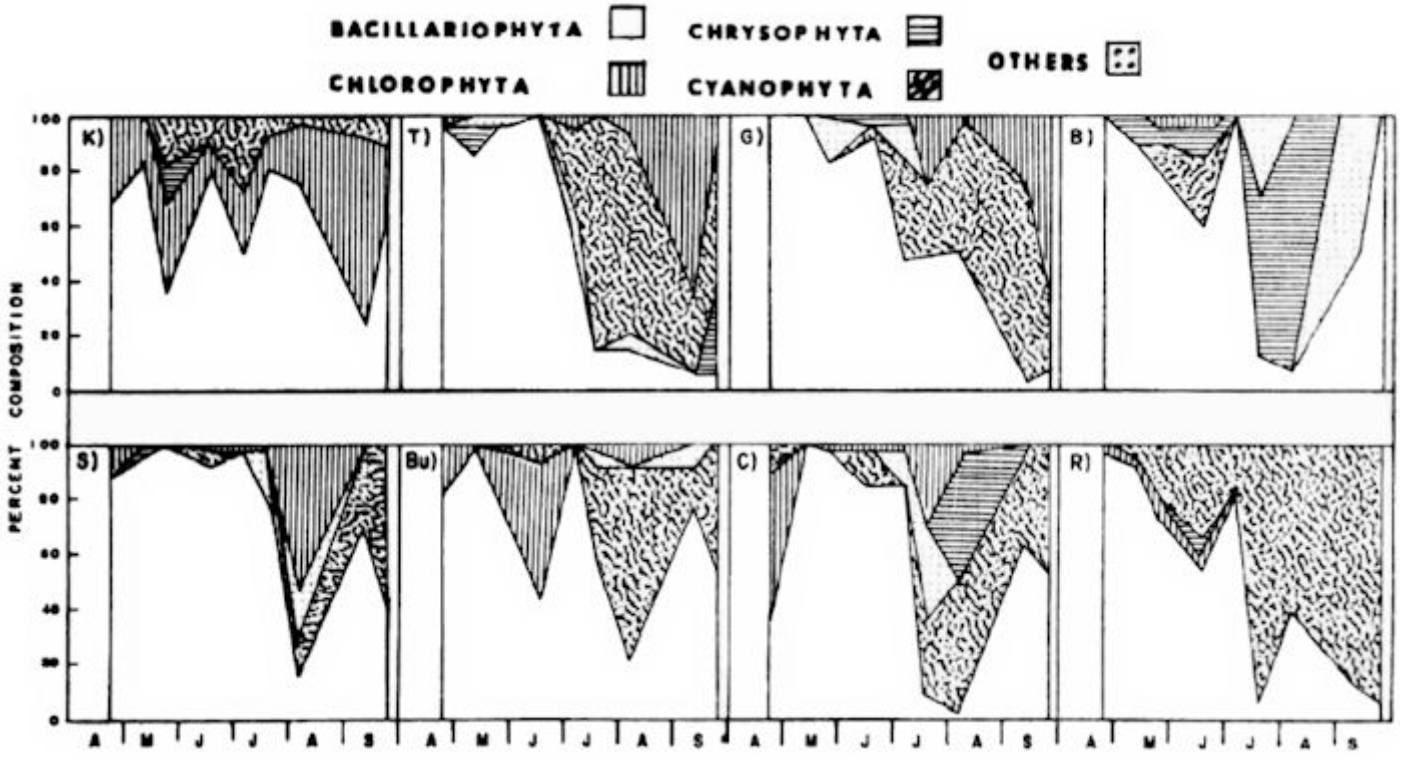

Figure 3. Comparisons between the phosphorus (P_1, P_2, P_3) of the seston and phytoplankton volumes (71 samples) or chlorophyll a concentrations (63 samples).

		P	$S\bar{y}.x$
$mg.m^{-3}$ P_1 =	0.3796 (10) + 0.9427 $cm^3.m^{-3}$ Algae	0.005	0.4948
$mg.m^{-3}$ P_2 =	0.2891 (10) + 0.1985 $cm^3.m^{-3}$ Algae	0.010	0.2958
$mg.m^{-3}$ P_3 =	0.1853 (10) + 0.1387 $cm^3.m^{-3}$ Algae	0.005	0.1508
$mg.m^{-3}$ P_1 =	0.3668 (10) + 0.9095 $mg.m^{-3}$ Chlor. a	0.005	0.5838
$mg.m^{-3}$ P_2 =	0.2920 (10) + 0.1768 $mg.m^{-3}$ Chlor. a	0.050	0.3190
$mg.m^{-3}$ P_3 =	0.1818 (10) + 0.1460 $mg.m^{-3}$ Chlor. a	0.005	0.1676

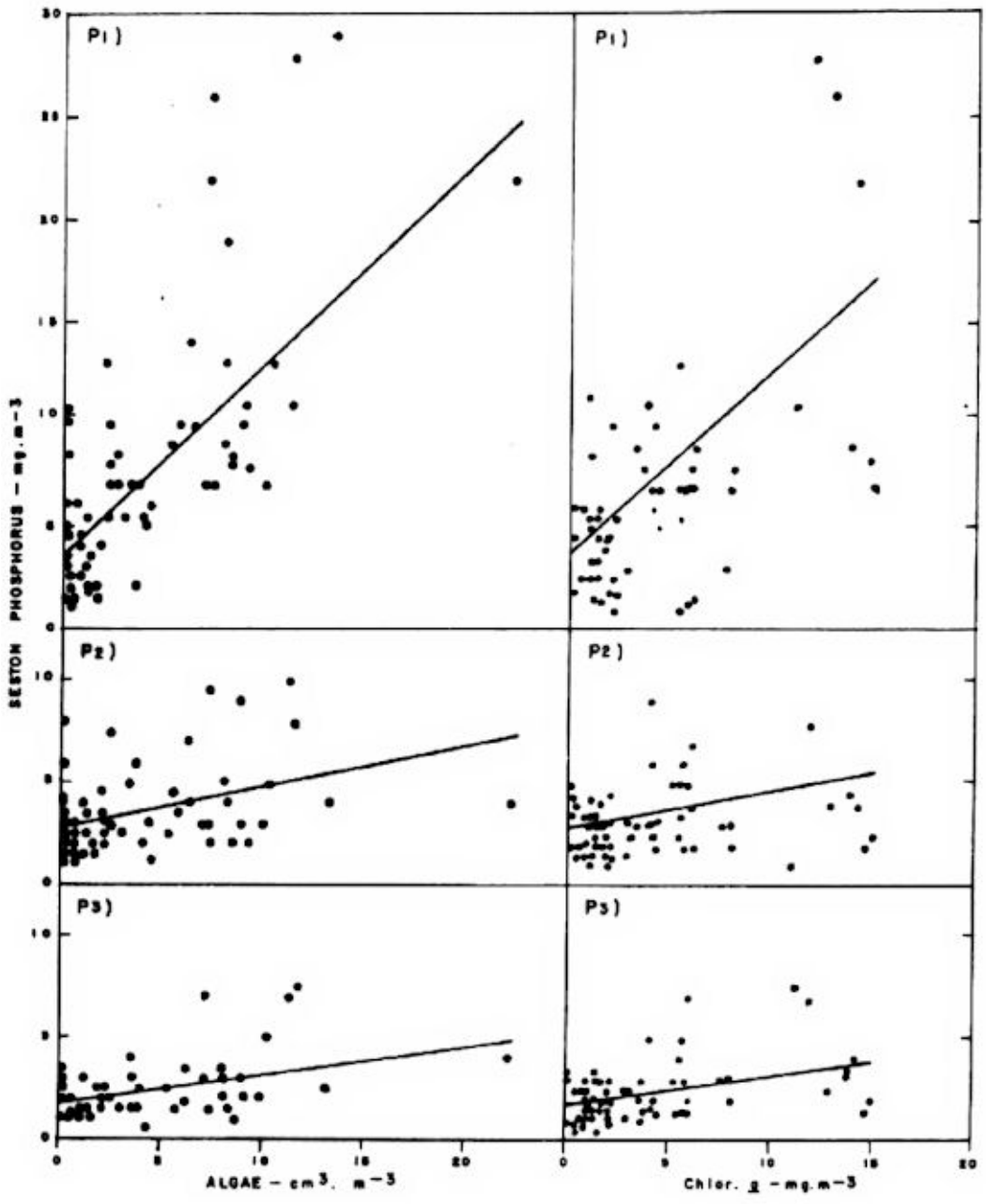

Figure 4. Comparisons between the nitrogen of the seston (N_1, N_2, N_3) and phytoplankton volumes (71 samples) or chlorophyll a concentrations (63 samples).

	P	$S\bar{y}.x$
$mg.m^{-3}$ N_1 = 0.4218 (10^2) + 0.1618 (10^2) $cm^3.m^{-3}$ Algae	0.005	0.1069 (10^2)
$mg.m^{-3}$ N_2 = 0.2632 (10^2) + 0.3833 (10) $cm^3.m^{-3}$ Algae	0.005	0.1747 (10)
$mg.m^{-3}$ N_3 = 0.1614 (10^2) + 0.2927 (10) $cm^3.m^{-3}$ Algae	0.005	0.1502 (10)
$mg.m^{-3}$ N_1 = 0.4609 (10^2) + 0.1618 (10^2) $mg.m^{-3}$ Chlor. a	0.005	0.1202 (10^2)
$mg.m^{-3}$ N_2 = 0.2586 (10^2) + 0.3662 (10) $mg.m^{-3}$ Chlor. a	0.005	0.2056 (10)
$mg.m^{-3}$ N_3 = 0.1516 (10^2) + 0.3009 (10) $mg.m^{-3}$ Chlor. a	0.005	0.1725 (10)

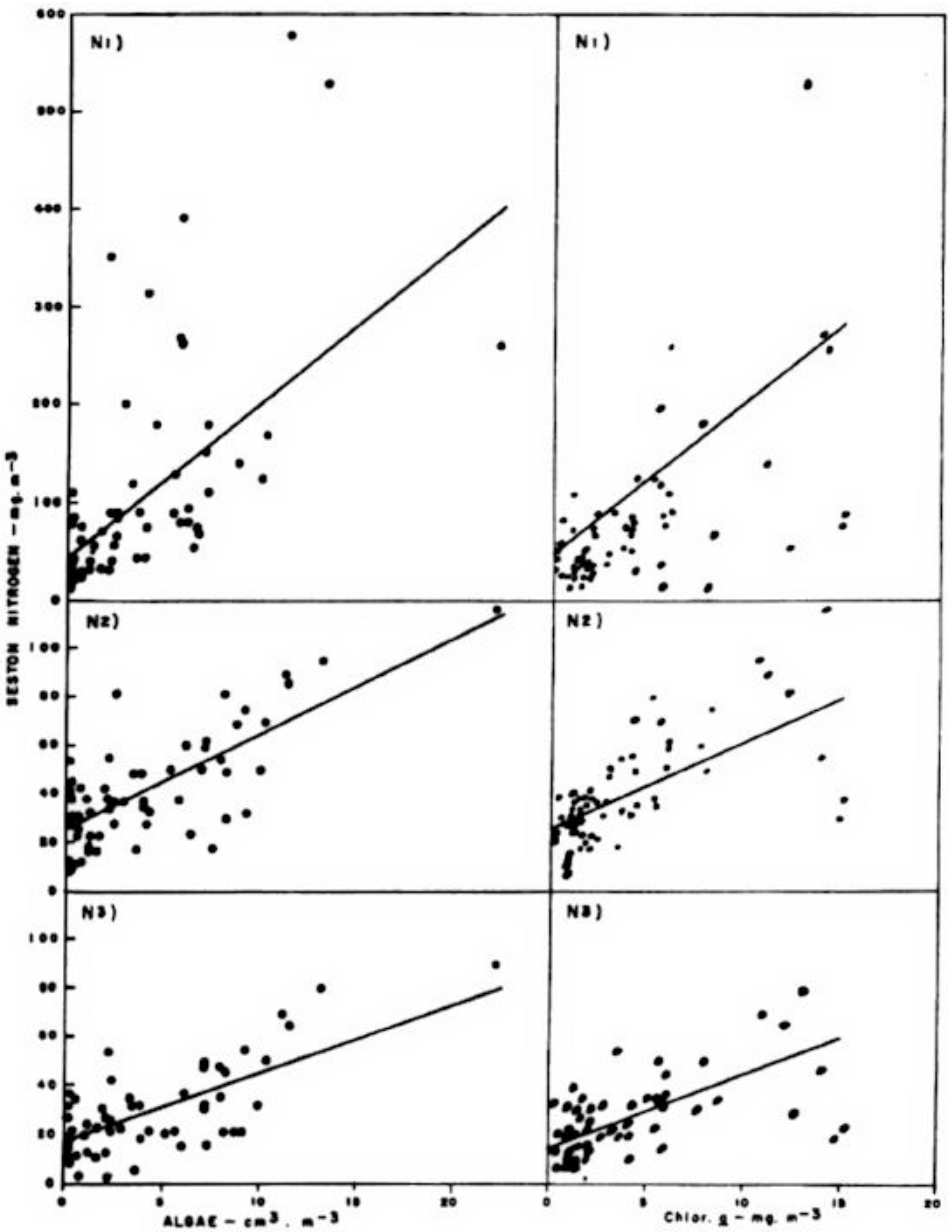

Figure 5. Comparisons between the carbon content (Cp) of the seston and phytoplankton volumes (71 samples) or chlorophyll a concentrations (63 samples)

		P	$S\bar{y}.x$
$g.m^3$ Cp = 0.5535 + 0.7638 (10^{-1}) $cm^3 .m^{-3}$	Algae	0.005	0.6521 (10^{-1})
$g.m^3$ Cp = 0.5451 + 0.8124 (10^{-1}) $mg.m^{-3}$	Chlor. a	0.005	0.7259 (10^{-1})

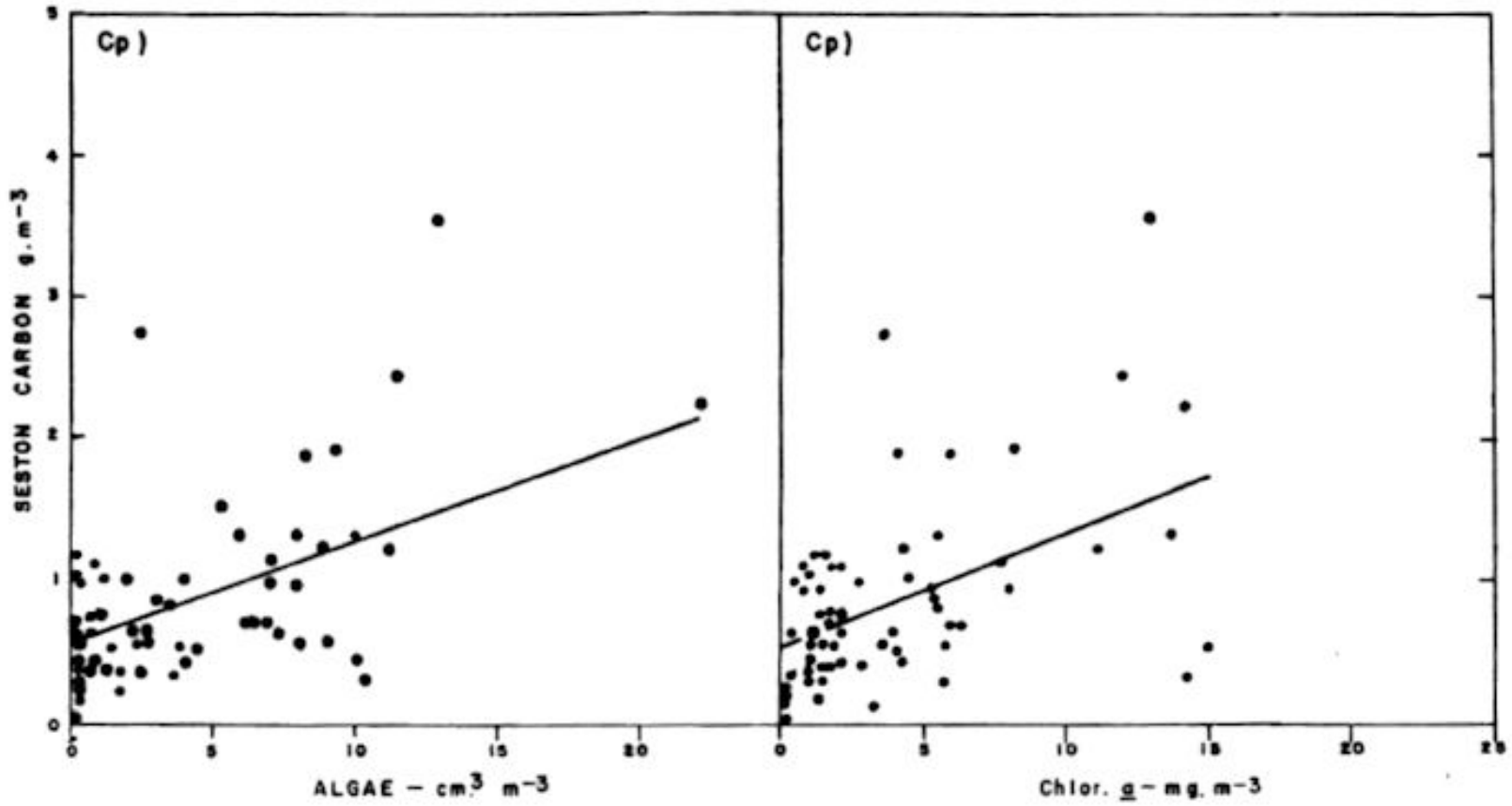

Table I. The mean, range and number of observations for each seston nutrient parameter - carbon, nitrogen, phosphorus, plus phytoplankton biomass and chlorophyll a.

Parameter	Mean	Range	Observations
Algae - $cm^3.m^{-3}$	3.72	0.02 - 22.23	71
Chlor. a - $mg.m^{-3}$	4.1	0.1 - 15.0	63
Seston Phosphorus - $mg.m^{-3}$			
P_1	7.3	1.5 - 29.0	71
P_2	3.6	1.2 - 10.0	71
P_3	2.7	0.5 - 7.5	71
Seston Nitrogen - $mg.m^{-3}$			
N_1	101.9	10.0 - 560.0	71
N_2	40.4	7.5 - 117.5	71
N_3	26.9	7.5 - 90.0	71
Seston Carbon - $mg.m^{-3}$			
Cp	820	20 - 3550	71

Table II. Ratios between the nutrients of the seston and standing crops of algae (cm^3) or chlorophyll a as derived from various regression equations of Figures 3, 4 5.

mg P_1 : cm^3 Algae	1.9:1	mg P_1 : mg Chlor. a	1.8:1
mg P_2 : cm^3 Algae	0.9:1	mg P_2 : mg Chlor. a	0.9:1
mg P_3 : cm^3 Algae	0.6:1	mg P_3 : mg Chlor. a	0.6:1
mg N_1 : cm^3 Algae	27.5:1	mg N_1 : mg Chlor. a	27.4:1
mg N_2 : cm^3 Algae	10.9:1	mg N_2 : mg Chlor. a	10.0:1
mg N_3 : cm^3 Algae	7.3:1	mg N_3 : mg Chlor. a	6.7:1
mg Cp : cm^3 Algae	226:1	mg Cp : mg Chlor. a	214:1

Table III. A comparison of nutrient biomass ratios obtained from the Bay of Quinte study (Christie, 1972b) and. the Trent Drainage Basin Study (Table II).

	Quinte	Trent		Quinte	Trent
mg P_1 : cm^3 Algae	1.5:1	1.9:1	mg P_1 : mg Chlor. a	1.2:1	1.8:1
mg P_2 : cm^3 Algae	0.6:1	0.9:1	mg P_2 : mg Chlor. a	0.4:1	0.9:1
mg P_3 : cm^3 Algae	0.4:1	0.6:1	mg P_3 : mg Chlor. a	0.3:1	0.6:1
mg N_1 : cm^3 Algae	20.6:1	27.5:1	mg N_1 : mg Chlor. a	17.2:1	27.4:1
mg N_2 : cm^3 Algae	9.9:1	10.9:1	mg N_2 : mg Chlor. a	8.4:1	10.0:1
mg N_3 : cm^3 Algae	6.6:1	7.3:1	mg N_3 : mg Chlor. a	5.8:1	6.7:1
mg Cp : cm^3 Algae	144:1	226:1	mg Cp : mg Chlor. a	103:1	214:1

REFERENCES

Christie, A.E., 1968 - Nutrient-phytoplankton relationships in eight Southern Ontario lakes. Ontario Water Resources Commission, Research Report No. 32, 37 pages.

Christie, A.E., 1972a - Phytoplankton studies in the Bay of Quinte 1. - Physical, Chemical and phytoplankton characteristics (in prep.)

Christie, A.E., 1972b - Phytoplankton studies in the Bay of Quinte II - Relationships between seston - phosphorus, nitrogen, carbon, and phytoplankton (in prep.)

Fitzgerald, G.P. and T.C. Nelson, 1966 - Extractive and enzymatic analysis for limiting or surplus phosphorus in algae. J. Phycol. 2:32-37.

Mullin, M.W., P.R. Sloan and R.W. Eppley, 1962 - Relationships between carbon content, cell volume and area in phytoplankton. J. Limmol. and Oceanog. 11:307-311.

Snedecor, G.W. and W.G. Cochran, 1957 - Statistical methods. Iowa State College Press, Fifth Ed. Ames Iowa, 534 pages.

Strickland, J.D.H, 1960 - Measuring the production of marine phytoplankton. Bull No. 222, Fish Res. Bd., Canada, 172 pages.

Vollenweider, R.A., 1970 - Scientific fundamentals of the eutrophication of lakes and rivers, with particular reference to nitrogen and phosphorus as factors in eutrophication. Organization for Economic Co-operation and Development, Paris, France, 159 pages.

- NOTICE -

This report is made in good faith and from information believed to be correct, but without any warranty, representation, endorsement, approval or guarantee of any kind whatsoever, whether express or implied, with respect thereto, and in particular, the Ministry disclaims any responsibility for the accuracy, completeness or usefulness of the report and does not represent or warrant that the use of the information contained in the report will conform to the law or may not infringe any rights under the law.

The Ministry and its employees and agents shall not be liable in any manner whatsoever in respect of the information contained in the report, and any use of such information shall be at the risk of the user.