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UPTAKE OF MINERAL NUTRIENTS BY CLADOPHORA SP. AND OSCILLATORIA SP. GROWN ON POLLUTED BOTTOM SEDIMENTS

BY

Alena Mudroch

UNPUBLISHED REPORT
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Abstract

The effects of two types of contaminated bottom sediments from lower Great Lakes on the uptake of major, minor and trace elements by Oscillatoria sp., Cladophora sp., Anabaena sp., and Pediastrum sp. were investigated with the electron microprobe. These species were innoculated in a sediment-water mixture and simultaneously into a culture media. Anabaena sp. and Pediastrum sp. grew only in flasks containing culture media but they did not grow in the sediment suspensions. Samples of Cladophora sp. and Oscillatoria sp. grown in the sediment suspension were collected and analyzed with electron microprobe.

Except for sulfur the demand of Oscillatoria sp. for major elements, such as P, K, Ca, Mg, Si, Na was similar in both the culture medium and sediment suspensions. Oscillatoria sp. did not take up Ni, Mn, Ti, Cr, Cl and took up Fe and Al only in trace amounts.

The uptake of major elements by Cladophora sp. from the investigated media was statistically different. However, the mineral composition of Cladophora sp. reflected, only to a limited extent, that of the ambient culture media. Ni, Ti, Hg, Pb were not detected. Fe and Al were found in trace amounts. Cr was detected in the species grown in a Hamilton Harbour suspension. Zn was determined in the species grown in the culture medium and in a Lake St. Clair sediment suspension.

Introduction

The major harbours of the Great Lakes, in particular Lake Erie, Lake Ontario and Lake Michigan belong to the severely polluted environment in the drainage basin. In recent years, many studies have focused on the bottom sediments of the Great Lakes and have demonstrated that increases in water contamination and soil erosion changed the chemical, physical, and biological properties of the sediments, in particular in the harbours and river mouths (Callender, 1969; Thomas, 1971; Kemp et al. 1972). Harbours and channels of the Great Lakes are regularly dredged to remove accumulated sediments, in general, uncontaminated from the channels and contaminated from the harbours. The disposal of uncontaminated sediments presents little concern, however, the disposal of contaminated harbour sediments in the open lake water may raise serious problems.

Several specific criteria for the assessment of bottom sediments contamination and toxicity were proposed: U.S. Environmental Protection Agency (EPA) criteria based on bulk-sediment composition, a "Standard Elutriation Test" proposed by EPA and U.S. Corps of Engineers (International Working Group on the Abatement and Control of Pollution from Dredging Activities, 1974) and various bioassay tests (Gannon and Beeton, 1969).

Gannon and Beeton (1969) investigated the effects of polluted harbour sediments on benthic organisms, benthic algae (*Cladophora sp.*), phytoplankton, unialgal cultures, zooplankton and *Daphnia pulex* in culture. They proposed five categories for bottom sediments.

1. toxic, avoided by benthic animals and not stimulating the growth of phytoplankton and Cladophora sp.

2. toxic to the test animals but stimulating the growth of phytoplankton and Cladophora sp.

3. partly toxic sediments killing some test animals but not affecting others; stimulating the growth of phytoplankton and Cladophora sp.

4. sediments of no special toxicity, and which do not stimulate the algal growth.

5. non-toxic,and stimulating the growth of phytoplankton but not the growth of Cladophora sp.

Algae have macro-and microelemental requirements which are related to cellular functions such as respiration, photosynthesis, and nitrogen fixation. Macro-elements, such as magnesium and calcium may have multiple functions. The essential micro-elements include iron, manganese, zinc, copper, cobalt, molybdenum, boron, vanadium, chloride, sodium, silicon and iodine. Specific species of algae require numerous elements, which must be apparently available in the substrate in a suitable form for survival and growth. It was demonstrated many times that there will be no growth if any one of the essential elements is removed and withheld from the algae (Jackson, 1968). On the other hand, excessive amounts of certain elements, for example, copper, (Sawyer, 1970, Gibson, 1972), zinc, cobalt (Coleman et al., 1971),lead (Whitton, 1970), may inhibit growth and kill algae.

The purpose of this study was to investigate the uptake of major, minor, and trace elements by selected algal cultures grown in recommended culture media on two types of sediments collected from Hamilton Harbour and Lake St. Clair using electron microprobe. Four algal species i.e. Pediastrum sp., Oscillatoria sp., Anabaena sp., and Cladophora sp. were selected for the experiment because of their natural abundance in the lower Great Lakes.

Materials and Methods

Surface samples of two different types of bottom sediments from Lake St. Clair and Hamilton Harbour were collected to a depth of 10 cm and used in this study. A part of each sample was freeze dried, ground to pass 200 mesh sieve and analysed; the major elements were determined by X-ray fluorescence and, trace elements were determined after $HCl-HNO_3$ extraction by Atomic Absorption Spectroscopy. Total nitrogen was determined with a Leco Nitrogen analyser (Table 1).

Ten grams of wet sediment were mixed with 50 ml of distilled water in 250 ml Erlenmayer flask, plugged loosely with cotton and placed on a lab bench at a temperature of approximately 20^oC until the sediment settled to the bottom and the overlaying solution was clear. Four flasks containing suspensions of Lake St. Clair sediment-distilled water and four flasks with Hamilton Harbour sediment-distilled water were prepared. Simultaneously, four Erlenmayer flasks each with 50 ml of Bristol modified solution with added soil extract (Eyster, 1968) were prepared as a control medium. Each of the flasks was innoculated with 2 drops of a suspension containing the following algae: Anabeana sp., Pediastrum sp., Oscillatoria sp., and Cladophora sp. (Ward's Natural Science Establishment Inc., Rochester, New York). After 14 days growth under artificial light (light intensity 500 foot-candles, sixteen-hour light period alternated with an eight-hour dark period) samples from the flasks were collected, washed three times with distilled water, centrifuged, and resuspended in distilled water. The cells were then mounted by a drop method on 200 mesh copper electron microscope grids coated with Formvar supporting film and evaporated carbon 50-100 Å thick.

All specimens were analysed by a combination of a Philips 300 electron transmission microscope (accelerating voltage: 8okV) and 707 EDAX electron microprobe analyser. Three factors i.e. thickness, mass per unit area, and local chemical composition were considered. The thickness of the algal cells was assumed to be uniform and therefore major variations of the emitted x-ray intensities were caused by the different local chemical composition and mass per unit area. Some methods proposed for the microanalysis of thick biological specimens measure the characteristic x-ray output (Hall, 1972), others included various refinements (Philbert, 1970).

The TEM program supplied by EDAX was applied for processing spectral data. This program calculates the atomic fraction ratios of the specified elements from the entered elemental intensities for each element, electron accelerating voltage and stored constants. Background subtraction and smoothing are performed automatically. Both intensities and fraction ratios along with the element symbols and specific x-ray lines are printed out. The objective of the experiment was to compare the local mass fractions of the same elements contained in algae; therefore, no reference measurements on standards were required.

Results and Discussion

The relative intensities and TEM corrected atomic fraction ratios along with means, standard deviations, and standard errors for Oscillatoria sp. are presented in Tables 2 and 3, those for Cladophora sp. in Tables 4 and 5. Anabaena sp. and Pediastrum sp. grew only in flasks containing culture media and failed to grow in the sediment suspensions.

"t"-test for two means at a level of significance of 5 per cent and 1 per cent was carried out, to show whether the media used (i.e. control culture medium and suspensions of Lake St. Clair and Hamilton Harbour sediments), had different effects on the uptake of elements by Oscillatoria sp. and Cladophora sp. The t-values were calculated from relative intensities and TEM corrected ratios for the following pairs of culture media:

Culture medium - Lake St. Clair suspension,
Culture medium - Hamilton Harbour suspension,
Lake St. Clair suspension - Hamilton Harbour suspension

The t-values for Oscillatoria sp. are shown in Table 6; those for Cladophora sp. in Table 7. The selected tabulated t-values are in Table 7. When the calculated t-values were higher than the tabulated ones at the significant levels selected, it was concluded that there was a statistically significant difference in element uptake.

The demand of Oscillatoria sp. for major elements such as P, K, Ca, Mg, Si, Na except for sulfur was nearly the same in the culture medium and sediment suspensions. Oscillatoria sp. did not take up Ni, Mn, Ti, Cr and Cl. Although Fe and Al were abundant in lake sediments their uptake by Oscillatoria sp. was observed only from the Lake St. Clair sediment suspension. The difference in sulfur uptake between the culture medium and Lake St. Clair sediment suspension was significant at the 1% level and the difference between the culture medium and the Hamilton Harbour sediment only at the 5% level. The culture medium and Hamilton Harbour sediment also differed in potassium uptake, but only when using TEM corrected ratios.

The uptake of major elements by Cladophora sp. from the three media was different. However, the mineral composition of Cladophora sp. reflected only to a limited extent that of the ambient culture media. Ni and Ti were not detected and are apparently completely rejected by Cladophora sp. Fe and Al were taken up only in trace amounts. Chromium was found in algae grown in the Hamilton Harbour sediment suspension but was not detected in the species grown in the culture medium and in the Lake St. Clair sediment suspension. Silicon was taken up in similar amounts by Cladophora sp. grown in all tested media. Lead, mercury and cadmium were not detected in any of the species although the Lake St. Clair sediment had a high Hg content and the Hamilton Harbour sediment a high Pb content. The t-values calculated from relative intensities and TEM ratios were either always significant (magnesium, calcium, sodium, potassium) or only significant when using relative intensities (sulfur, chlorine).

Schneider (1972) studied the over-all concentrations of a minor or trace element in small particulate material with electron microprobe and concluded that local variations may be caused by quite different distributions of the same element in the different phases of the specimens. This observation could be applied to the explanation of some high standard deviations for specific elements in this study in particular potassium, phosphorus and calcium, (Tables 2-5).

The use of the electron microprobe analyser allowed the determination of element uptake by selected algal species grown in various culture media and the assessment of algal role in the studied environment.

Research expanded on the element uptake by other algal species will certainly contribute to a better understanding of the role of algae in the food chain of aqueous environment containing contaminated bottom sediments.

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Table 1

Chemical composition of bottom sediments and elutriates

Element ppm	Hamilton Harbour sediment	Hamilton Harbour water	Lake St. Clair sediment	Lake St. Clair water
Cu	115	0.08	30	0.07
Zn	4,800	0.8	62	0.27
Pb	580	n.d.*	28	not analysed
Co	23	n.d.*	11	n.d.*
Ni	49	0.05	21	0.04
Mo	< 2	n.d.*	< 2	n.d.*
Cd	11	n.d.*	4	n.d.*
Cr	150	n.d.*	15	n.d.*
Sr	50	not analysed	25	not analysed
Mn	2,150	2.7	275	0.07
Na	450	74	150	16
K	14,130	20	2,300	8
Ca	70,500	230	88,500	500
Mg	11,500	90	29,500	39
Fe	137,000	0.06	16,500	0.04
P	2,700	0.07	237	not analysed
% N	0.4	0.04	0.1	not analysed
ppb Hg	1,000	n.d.*	4,280	n.d.*

*n.d. not detected

Table 2

Oscillatoria sp.

(Relative intensities %)

	#	Si	Al	Fe	Mg	Ca	Na	K	Ti	Mn	Ni	P	S	Cl	Cr	Zn
Oscillatoria sp. culture	1	5.8		1.8	3.2	12.9	1.5	41.7				19.9	12.7			
	2	2.0			3.2	9.0	.6	40.7		1.1		30.0	14.2			
	3	1.1	1.3		1.9	5.7	.7	38.9				29.0	20.9			
Mean		2.6			2.9	9.2	0.5	40.4				26.3	15.9			
Standard deviation		2.9			0.7	3.6	0.4	1.4				5.5	4.3			
Standard error		1.6			0.4	2.0	0.2	0.6				3.2	2.5			
Oscillatoria - L. St. Clair	1	3.5	.6	.3	5.5	4.4	.9	26.0				54.0	4.7			
	2	3.5	.3	.5	3.9	16.3	1.3	30.0	.5			34.0	9.5			
	3	3.2	.4		6.7	2.5	1.0	26.1				57.0	3.0			
	4	2.2	.3	1.1	3.8	9.1	.5	32.0	.5	.1		38.1	11.7			
	5	2.4	1.3	.4	4.7	5.8	1.3	32.5				45.0	5.9			
	6	2.8	.1	.3	3.0	10.6	1.8	55.0	.3			20.0	6.0			
	7	2.7	.1	.5	2.8	5.0	.5	39.0				45.0	4.0			
	8	2.5	.1	.2	2.3	10.2	1.6	54.1				22.7	5.2			
	9	2.1	.9	.4	3.5	6.4	2.9	42.2	.2	.3		36.0	5.0			
Mean		2.7	0.4	0.4	4.0	7.8	1.3	37.4				39.0	6.1			
Standard deviation		0.5	0.4	0.3	1.4	4.2	0.7	11.0				12.6	2.7			
Standard error		0.1	0.1	0.1	0.4	1.4	0.2	3.7				4.2	0.9			
Oscillatoria sp. Hamilton Harbour	1	3.7	.5	0.1	4.9	5.0	1.5	29.6		.3	.2	54.0	5.3			
	2	.9		.7	2.7	20.0	5.3	40.8	.2			11.3	18.1			
	3	4.0	.8		6.8	2.0	2.0	25.9	.1		.03	55.5	3.0			
	4	1.1			3.4	7.6	2.6	38.2		.5		43.7	3.2			
	5	3.5	.6	.1	6.3	4.2	.9	29.3				51.5	3.6			
	6	3.3		.8	1.6	7.0	1.4	41.7		.9		29.9	14.7			
	7	2.2		.6	1.8	16.5	.6	35.5			1.0	33.5	8.3			
	8	2.9	.2	.5	4.9	7.7	1.7	35.1				44.8	2.1			
	9	2.5	0.1	.2	4.0	12.4	2.1	33.6		.7		37.0	7.5			
Mean		2.6	0.3	0.3	4.0	9.1	2.0	34.4				40.1	7.5			
Standard deviation		1.1	0.4	0.3	1.8	5.9	1.3	5.4				14.0	5.9			
Standard error		0.3	0.1	0.1	0.6	2.0	0.4	1.8				4.6	2.1			

Table 3

Oscillatoria sp.

TEM Corrected Ratios (%)

	#	Si	Al	Fe	Mg	Ca	Na	K	Ti	Mn	Ni	P	S	Cl	Cr	Zn
Oscillatoria culture	1	7.7		0.9	12.4	6.8	19.9	23.1				18.4	9.7			
	2	2.9			13.9	5.3	8.4	25.2				31.1	12.2			
	3	1.6	2.9		8.4	3.4	11.2	24.3		0.4		30.4	18.0			
Mean		4.0			11.5	5.1	13.1	24.2				26.6	13.3			
Standard deviation		3.2			2.8	1.7	6.0	1.0				7.1	4.2			
Standard error		1.8			1.6	0.9	3.4	0.6				4.1	2.4			
Oscillatoria L. St. Clair	1	4.0	1.0	0.1	19.2	2.1	10.7	13.3				46.3	3.3			
	2	4.3	0.6	0.2	15.0	8.6	16.1	16.7	0.2	0.02		32.0	7.3			
	3	3.4	0.7		22.0	1.1	11.8	12.6				46.0	1.9			
	4	2.9	0.6	0.6	15.0	5.0	10.2	18.5	0.4	0.05		36.8	9.3			
	5	2.8	2.2	0.2	16.7	3.3	14.2	17.0		0.03		39.3	4.2			
	6	3.6	0.2	0.2	11.7	5.8	23.3	32.3	0.2			19.7	4.8			
	7	3.6	0.1	0.3	11.8	2.9	7.3	23.8				46.0	3.4			
Mean		3.5	0.9		15.1	4.3	14.3	20.4				36.1	4.8			
Standard deviation		0.5	0.8		4.1	2.4	5.5	7.4				10.5	2.3			
Standard error		0.1	0.3		1.4	0.8	1.9	2.4				3.7	0.8			
Oscillatoria sp. Hamilton Harbour	1	4.0	0.8		16.2	2.3	16.2	14.4		.1	0.08	42.3	3.5			
	2	0.8		0.2	7.5	7.8	49.1	16.8	.07			7.8	10.3			
	3	3.8	1.1		20.3	0.8	20.2	11.3	.04		.01	40.4	1.8			
	4	1.2			11.4	3.4	28.0	18.5		0.2		35.3	2.1			
	5	3.8	1.0	.04	21.4	2.0	10.4	14.5				42.5	2.4			
	6	4.3		0.4	6.3	4.0	17.0	25.1		0.5		30.1	12.1			
	7	3.3		0.3	6.6	10.7	7.7	24.4			.6	38.4	7.9			
	8	3.2	.3	0.2	16.9	3.6	19.6	17.5				37.4	1.5			
	9	2.8	0.07	0.1	14.0	5.9	24.5	16.9	.01	0.3		31.1	5.2			
Mean		2.8		0.2	13.4	4.5	21.4	17.7				33.9	5.2			
Standard deviation		1.4		0.2	5.7	3.1	12.1	4.5				10.7	3.9			
Standard error		0.4		0.1	1.9	1.0	4.0	1.5				3.5	1.3			

Table 4

Cladophora sp.

(Relative intensities %)

	#	Si	Al	Fe	Mg	Ca	Na	K	Ti	Mn	Ni	P	S	Cl	Cr	Zn
Cladophora sp. culture	1	10.0	.3	1.1	0.1	26.8	1.7	23.6				15.4	8.8	8.8		3.5
	2	4.4			2.4	23.3	2.8	34.9				15.6	5.4	6.2		4.8
	3	1.3	1.3		0.1	28.6	3.1	25.0				21.7	6.7	7.7		6.2
Mean		5.2			0.8	26.2	2.5	27.8				17.5	0.9	7.5		4.8
standard deviation		4.4			1.3	2.7	0.7	6.1				3.5	1.7	1.3		1.3
standard error		2.5			0.7	1.5	0.4	3.5				2.0	1.0	0.7		0.7
Cladophora L. St. Clair	1	4.3		.7	3.2	7.5		40.1	.3			29.9	10.4	1.6	1.5	
	2	3.3	1.9		4.9	5.8	.6	37.0		.2		34.5	9.3	1.4	1.0	.1
	3	2.4	.4	.3	6.6	4.0	1.6	26.0				53.0	5.4			
	4	1.5			2.4	10.0	.1	50.0		.6		24.2	10.0	3.0		
	5	2.0			3.5	6.7		43.1				32.6	13.6	2.9		
	6	5.6	.5		2.3	2.2	.5	33.4				50.0	3.9	.5		
	7	2.7			2.8	4.9		50.0				30.0	6.8	6.0		
Mean		3.1			3.6	5.3	0.4	39.9				36.3	8.5	2.2		
standard deviation		1.4			1.5	2.4	0.6	8.7				10.8	3.3	2.0		
standard error		0.5			0.6	0.8	0.2	3.3				4.1	1.2	0.7		
Cladophora Hamilton Harbour	1	1.4		5.1	3.6	14.0	3.6	13.0		.9		24.0	20.0	13.0	3.0	4.5
	2	2.0	.9		3.5	7.0	3.0	9.0		1.3		31.0	11.0	23.0	3.0	5.0
	3	4.3		.8	2.2	5.0	2.0	14.0	.8	.1		42.0	9.0	12.0	2.3	6.0
	4	1.1	.5	1.0	1.1	7.0	.9	20.0	1.0	1.3		32.0	15.7	8.2	11.0	5.2
	5	3.0	1.3	.4	4.4	11.8	4.6	6.4		.2		22.4	18.9	20.6	1.2	5.8
	6	2.6		.7	4.8	5.0	2.0	12.0		.2		30.0	12.0	16.0	2.0	4.5
Mean		2.4		1.3	3.2	8.3	2.6	12.4		0.6		31.2	14.4	15.4	3.7	5.1
Standard deviation		1.1		1.8	1.4	3.7	1.3	4.6		0.6		7.3	4.4	5.5	3.6	0.5
Standard error		0.4		0.77	0.5	1.5	0.5	1.9		0.2		3.0	1.8	2.2	1.4	0.2

Table 5

Cladophora sp.

TEM Corrected Ratios (%)

	#	Si	Al	Fe	Mg	Ca	Na	K	Ti	Mn	Ni	P	S	Cl	Cr	Zn
Cladophora culture	1	11.3	0.5	0.4	0.2	12.8	19.4	12.1				13.2	6.6	5.3		17.9
	2	4.2			6.9	9.4	27.0	14.9				11.1	3.2	3.2		20.6
	3	1.2			0.3	11.1	29.1	10.3				14.9	3.8	3.8		25.7
Mean		5.5			2.4	11.1	25.1	12.4				13.0	4.5	4.1		21.4
Standard deviation		5.2			3.8	1.7	5.1	2.3				1.9	1.8	1.0		3.9
Standard error		3.0			2.2	1.0	2.9	1.3				1.1	1.0	0.6		2.3
Cladophora L. St. Clair	1	67		0.4	15.4	4.9		28.6	0.2			35.0	10.0	1.3	0.8	
	2	4.2	3.7		19.0	3.1	8.0	21.1		0.1		33.0	7.3	1.0	0.5	0.4
	3	2.3			11.7	7.1	1.5	34.6		0.3	0.1	29.8	9.8	2.6		
	4	2.8	0.6		15.0	4.0	1.4	27.0				34.1	11.7	2.2		
	5	6.7	1.2		9.1	1.2	7.1	19.6				48.8	3.1	0.4		
	6	3.8			12.9	3.0	1.6	31.1	0.1	0.06		36.4	5.6	4.9		
	7	3.6		0.4	2.0	4.1		37.8	1.0			40.2	10.9	0.5		
Mean		4.3			12.1	3.9	2.8	28.5				29.6	8.3	1.8		
Standard deviation		1.7			5.4	1.8	3.3	6.6				12.5	3.1	1.5		
Standard error		0.6			2.0	0.7	1.2	2.5				3.9	1.1	0.6		
Cladophora Hamilton Harbour	1	1.4		1.9	11.0	5.9	36.2	5.9		0.3		17.5	12.5	6.8	1.1	7.0
	2	2.1	1.4		11.0	3.1	28.9	4.1		0.5		23.5	6.7	2.1	0.2	4.1
	3	4.8		0.3	7.2	2.1	20.7	7.0	0.4	0.1		35.0	6.6	4.8	0.6	17.5
	4	2.0	1.3	0.7	6.2	5.6		17.1	0.7	0.9		44.1	17.9	2.0	1.8	
	5	2.7	1.8	0.1	11.9	4.4	41.6	2.5	0.01	0.1		14.8	10.3	2.7	0.1	6.4
	6	2.9		0.3	16.0	2.3	25.8	5.7		0.1		29.9	8.2	2.9	0.3	6.4
Mean		2.6		0.5	10.5	3.9	25.5	7.0		0.3		27.4	10.3	3.5	0.6	6.9
Standard deviation		1.1		0.7	3.5	1.6	14.5	5.1		0.3		11.0	4.3	1.9	0.6	5.8
Standard error		0.4		0.3	1.4	0.6	5.9	2.1		0.1		4.5	1.7	0.7	0.2	2.3

Table 6

Oscillatoria Sp.

t Statistic of Two Means - TEM Corrected Ratios (%)

	Si	Mg	Ca	Na	K	P	S	Degrees of freedom	Tabulated t-Values Significance Levels 0.01	0.05
Culture medium Lake St. Clair	0.79	1.34	0.55	0.30	0.72	1.41	4.31	9	3.25	2.26
Culture Medium Hamilton Harbour	0.86	0.49	0.34	1.11	2.37	1.08	3.01	10	3.17	2.23
Lake St. Clair Hamilton Harbour	0.99	0.69	0.14	1.30	1.01	0.42	0.25	16	2.92	2.12

Table

Oscillatoria Sp.

t Statistic of Two Means - Relative Intensities

	Si	Mg	Ca	Na	K	P	S	Degrees of Freedom
Culture medium Lake St. Clair	0.25	1.45	0.51	0.81	1.84	1.65	4.68	9
Culture Medium Hamilton Harbour	0.33	0.93	0.45	1.29	1.44	2.58	2.40	10
Lake St. Clair Hamilton Harbour	0.22	0.03	0.81	1.36	0.74	0.17	0.58	16

Table 7

Cladophora Sp.

t Statistic of Two Means - TEM Corrected Ratios (%)

	Si	Mg	Ca	Na	K	P	S	Cl	Degrees of Freedom	Tabulated t-Values Significance Levels 0.01	0.05
Culture medium / Lake St. Clair	0.61	2.75	5.83	8.43	3.96	6.31	1.93	2.23	8	3.36	2.31
Culture medium / Hamilton Harbour	1.62	3.16	6.10	0.04	6.00	2.16	2.18	0.46	7	3.50	2.36
Lake St. Clair / Hamilton Harbour	1.95	0.62	0.01	4.04	6.40	1.91	0.98	1.78	11	3.11	2.20

Table

Cladophora Sp.

t Statistic of Two Means - relative intensities

	Si	Mg	Ca	Na	K	P	S	Cl	Degrees of Freedom
Culture medium / Lake St. Clair	1.22	2.70	11.48	4.93	2.15	2.84	0.73	4.18	8
Culture medium / Hamilton Harbour	1.57	2.48	7.30	0.18	4.25	2.98	2.72	2.35	7
Lake St. Clair / Hamilton Harbor	0.98	0.49	1.39	4.14	6.90	0.97	2.75	5.92	11