Phytoplankton community composition effects on phosphorus sedimentation dynamics in Lake Erie

by

Sunniva Bruce Ronzio

A thesis
presented to the University of Waterloo
in fulfilment of the
thesis requirement for the degree of
Master of Science
in
Biology

Waterloo, Ontario, Canada, 2007

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Sunniva Bruce Ronzio

Abstract

Cultural eutrophication is caused by the excess addition of phosphorus to aquatic ecosystems, and has long been a water quality management issue in Lake Erie. Despite successful reductions in external loading of phosphorus in Lake Erie the in lake total phosphorus (TP) concentrations are increasing recently and symptoms of eutrophication are apparent. In this study I examined the sedimentation velocity of particulate phosphorus and how it is affected by stratification and plankton community composition over the growing season. Diatoms had the highest sedimentation velocities and a shift to slower settling species with greater form resistance (*Synedra* sp. and *Fragilaria* sp.) was observed during the stratified period possibly in response to the shallower mixed layer. No significant variation in sedimentation velocity was found with trap depth, plankton size or temperature; hence the individual plankton cells were employing methods to change their sedimentation velocity in accordance with changing environmental conditions. Phosphorus sedimentation was most closely related to silica sedimentation, which largely represents the sedimentation of the diatoms. Thus any shifts in community composition will affect phosphorus-settling rates.

The sedimentation rate of phosphorus decreased from June 2nd until August 26th during the stratified period at station84 and from June 2nd to August 5th at station 452. The decline of total phosphorus was less than the sedimentation rate, hence, sediment resuspension and redistribution from the littoral sediments along with atmospheric deposition are important sources of phosphorus to the central and eastern basins of Lake Erie.

The sedimentation rates of P, N and C did not follow the Redfield ratio. The sedimentation velocity of P was much less than that of C and N, indicating that P is conserved in the epilimnion and possibly that C and sedimentation contains more non-living material. Therefore, modelling phosphorus sedimentation after carbon and nitrogen sedimentation is inappropriate. Laboratory sedimentation towers can be used to measure phytoplankton sedimentation velocity including net upward movement, which traditional sedimentation traps are unable to do. Determination of the sedimentation velocity of the phytoplankton community to variables such as light, temperature and nutrient status, using this method, may eventually lead to a dynamic phosphorus model that could more effectively reduce eutrophication effects in Lake Erie.

Acknowledgements

In reviewing my list of all those who helped get me through some of the toughest years of my academic career, I quickly realized how truly blessed I am to be surrounded and supported by so many people. First of all, I have to thank my supervisor Dr. William Taylor, whose unbreakable patience and enthusiasm for all things phosphorus allowed for the completion of this thesis. Secondly I must thank my committee members, Dr. Robert Hecky and Dr. Mike Stone for their helpful suggestions throughout this process. Murray Charlton, Jacqui Milne, Tina Mamone, Steve Smith, Vi Richardson, Chris Marvin and everyone in tech-ops at C.C.I.W. in Burlington, Ontario for providing the resources, knowledge and drives to the LIMNOS. On that note, I must thank the captain and crew on the LIMNOS who never failed to make me feel at home out on the water. I must especially thank Larry White for all the delicious "brain food".

There are many in the University of Waterloo community that I must thank. Dave Depew, Ralph Dickhout and Yuri Kozlov for their technical analysis and guidance. Dr. Stephanie Guildford for never failing to provide a much needed morale boost from time to time. All of my fellow graduate students in UWAEG for their endless support and suggestions, especially Rebecca North for all my initial training in the wonderful world of phosphorus and Sunita Sarkar for constantly giving me a motivational push when I simply did not want to move.

Above all, I thank my family whose unconditional love and support got me through it all. My mother for giving me a landing pad when I was frustrated and a coffee when I needed to get going again. My father for providing suggestions and "technical support" and my brother who never failed to ask, "Are you done your

thesis yet?" Most of all, my husband Charlie, for just being there, no matter how I felt, or how I acted. For being everything I will ever need.

This has been quite the journey and I say with confidence that I will remember each and every person I met along the way.

Table of Contents

List of Tables

List of Figures

Introduction

Limnologists have long recognized phosphorus (P) as the vital nutrient controlling algal growth in freshwater systems (Kalff, 2002). Total phosphorus (TP) concentrations have been directly linked to phytoplankton biomass, production and community composition (Kalff, 2002). In many natural systems, TP levels are low leading to low algal biomass. However, increasing industrialization and agriculture has increased inputs of phosphorus in the form of fertilizer, sewage (including phosphorus-enriched detergents), and industrial waste into many lakes. The result is often an increase in algal biomass and, in many instances, an increase in the amount of noxious and toxic algae causing foul tastes and odours in drinking water, low dissolved oxygen concentration, poor water quality and toxin production (Vollenwieder, 1968; Wetzel, 2001). Hence, P management strategies are critical to both ecosystem and human health.

Mass balance models, which relate the amount of P input and cycling to the total phosphorus (TP) in lakes, are often used to understand and manage the effects of eutrophication. Typical P mass balance models include rock weathering and runoff, precipitation and anthropogenic influences as input variables and outflow, biomass removal, and both temporary and permanent burial in the sediment via sedimentation as output variables (Vollenwieder, 1968). One apparent problem with these models is that they often treat a system as static by using annual measurements or measurements during a single season although it is well documented that P loading and sedimentation are dynamic processes that change throughout the seasons. For example, Dillon and Rigler (1974) created a model that would predict summer algal biomass from spring total phosphorus

(TP) concentration. This model was based on Sakamoto's (1966) observation that chlorophyll *a* and TP could be used to measure the effects of eutrophication. Baines and Pace (1994) used productivity and sedimentation rates measured during stratification in their model. Studies that examine year round changes in inputs and losses from a system may lead to improved eutrophication management strategies.

After loading, sedimentation is the key process determining TP in lake systems. Sedimentation is defined as the settling of both organic and inorganic particles from the epilimnion, referred to as suspended particulate matter (SPM). SPM may include: phytoplankton, zooplankton and their detritus, allochthonous particles from the surrounding catchment and resuspended lake bottom sediment (Kalff, 2002). Sedimenting material leaving the epilimnion can have two fates: it can be mineralized as it passes through the meta and hypolimnion or at the sediment surface; or it can be buried in the sediments. Once this fraction of phosphorus is lost from the epilimnion it is unavailable to plankton until periods of mixing and, even then, some of that P is permanently retained in the sediment (Wetzel, 2001). During stratification, when loading is typically low, TP generally declines as a result of sedimentation. Guy *et al.* (1994) found that the sedimentation of P during periods of stratification caused a loss of up to 60% of TP from the epilimnion in central Ontario lakes.

A review of the literature (my unpublished review) suggests that a pattern exists among lakes with respect to their P sedimentation rates (Fig. 1), expressed as the amount of P sedimenting per area per time; 97% of data points surveyed fell within the range of 0-10 mg $Pm^{-2}d^{-1}$ with a mean sedimentation rate of 2.8 mg

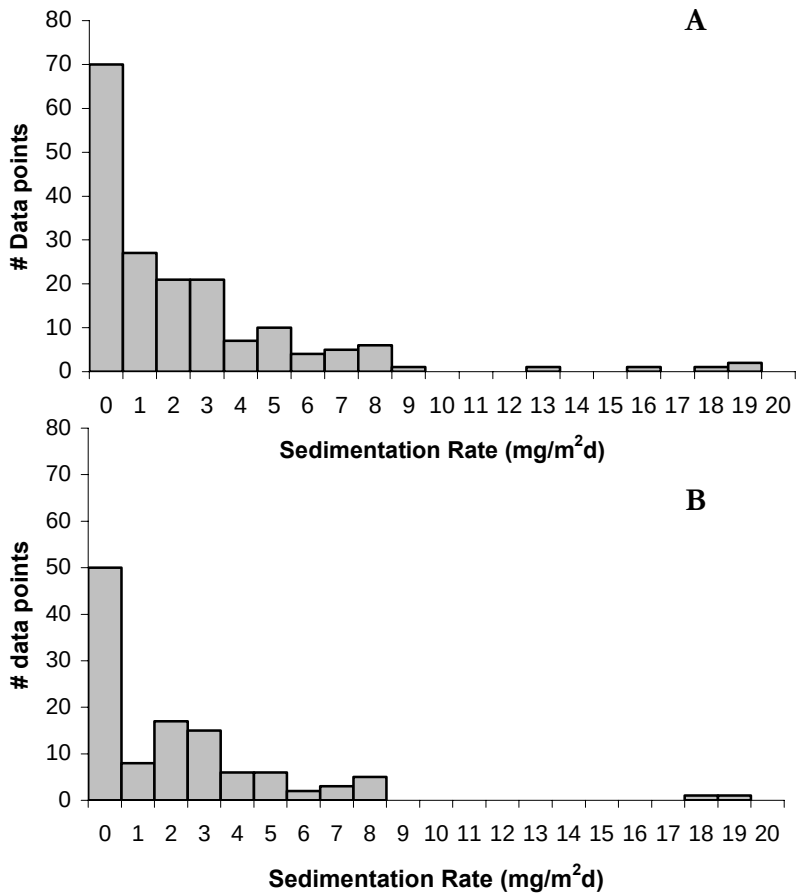


Figure 1 – Frequency distribution of sedimentation rates for the 41 lakes surveyed for my unpublished review. A) includes all data points b) includes only those sedimentation rates calculated during stratification.

$Pm^{-2}\,d^{-1}$. When the sedimentation rate was compared to the TP in the system, there appeared to be a strong relationship among lakes within the range of 0-150 ug/L TP. Thus it seems the water-column concentrations of P are one variable controlling the sedimentation rate of P in a system. This agrees with Guy *et al.* (1994) who found that in larger, oligotrophic Ontario lakes, the greater the amount of TP at the onset of stratification, the greater the amount of P lost over the season.

The relationship between P sedimentation and TP suggests that sedimentation velocity of P is relatively invariant (Fig. 2) (my unpublished review). Dividing sedimentation rate by particulate P yields a sedimentation velocity in the units of distance $time^{-1}$. As with P sedimentation rate, a review of the literature shows a pattern exists for P sedimentation velocity among lakes with an average sedimentation velocity of 36.175 cm/d (Fig. 3). Interestingly, when the data were edited to include sedimentation velocities during periods of stratification only, the average sedimentation velocity decreased dramatically to 18.995 cm/d. A 2-tailed t-test confirmed a significant difference between these two means.

According to Stokes law (designed to examine the frictional force a continuous viscous fluid will exert on a falling spherical object), the sedimentation velocity of spherical particulate matter (V_s) under gravity (g) will increase with the square of the radius (r^2) and the density (p_p) of the sphere and decrease with increasing density (p_f) and viscosity (n) of the medium. The latter is affected by temperature where an increase in temperature leads to a decrease in water's

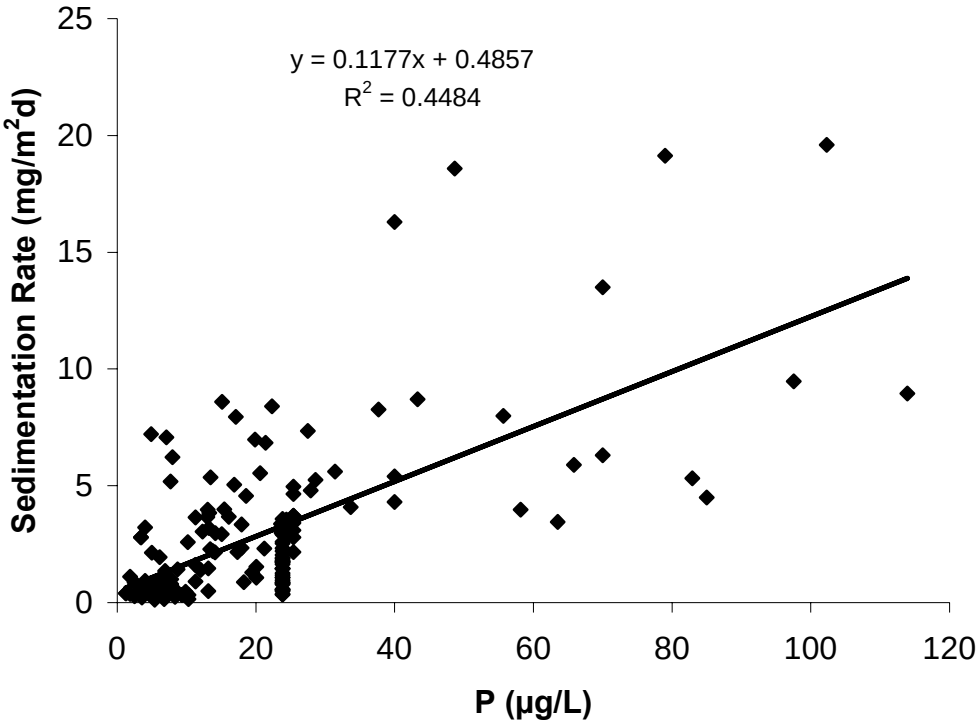


Figure 2 – Sedimentation rate of phosphorus vs total phosphorus for 41 lakes surveyed for my unpublished literature review.

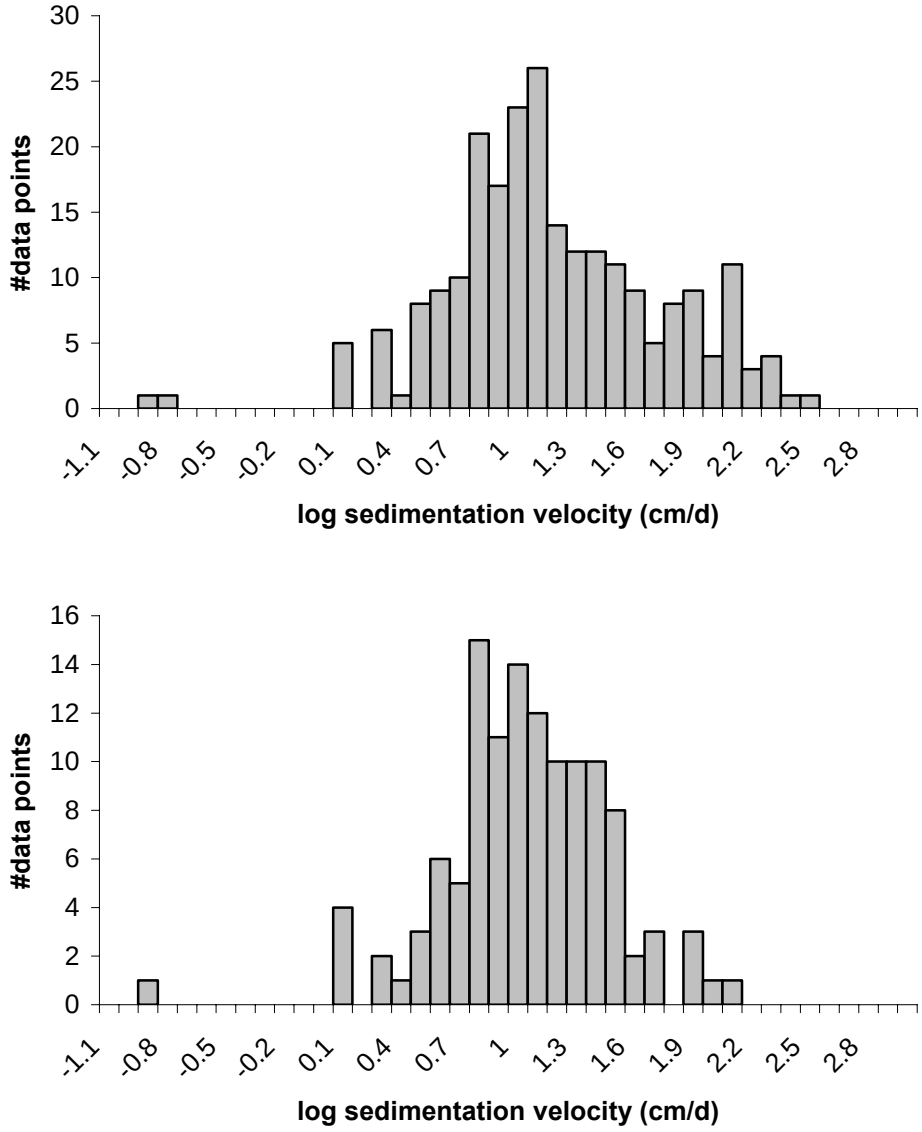


Figure 3 - Frequency distribution of the sedimentation velocity measured for 43 lakes for my unpublished literature review A) includes all data B) includes only those data points measured during stratification

$$V_s = \frac{2r^2 g\,(p_p - p_f)}{9n}$$

viscosity. Thus an increase in temperature can lead to an increase in the sedimentation velocity of the particle (Hutchinson, 1967). A relationship between mean particle size (μm) and sedimentation reported by Mazumder *et al.* (1989) and Guy *et al.* (1994) showed shifts in plankton size towards larger plankton that led to increased sedimentation rates. Larocque *et al.* (1996) determined that algal mean length was a stronger determinant of sedimentation rate than algal biomass with an increase in sedimentation rate with increasing mean algal length up to 20 μm. Poister and DeGuelle (2005) found that in diatom-dominated systems, particles > 20 μm mean diameter were more likely to contribute to sedimentation, with 80% of trap material being comprised of this size class during the spring season. However, during the stratified season only 46% of the trap material was comprised of the large size class indicating a shift in the community composition from large to small and possibly more buoyant species. This shift was also reflected in the high carbon and phosphorus sedimentation rates measured in the spring and the lower measurements during stratification. Other factors known to increase sedimentation velocity are calcite precipitation which is the formation of calcite crystals around small particles such as bacteria or tiny algae (Kalff, 2002), the packaging of particles into zooplankton fecal pellets and particle aggregation through physical collisions as the particles sink or via microbial action (Kalff, 2002).

Hutchison (1967) showed that biological particles can reduce their sedimentation velocity as a survival technique in order to remain in the mixed layer. Their strategies can include gas vacuoles (Thomas and Walsby, 1985), spiny projections and mucous production as well as the build-up of hydrocarbons (Fogg, 1965) to reduce their density. Flagella and cilia can also be used to actively move in the water column (Wetzel, 2001). Hence, the simple relationship between particle size and sedimentation velocity predicted by Stokes Law may be obscured by other factors when dealing with phytoplankton. In fact, *in situ* studies by Hudson and Taylor (2005), Poister (1995) and Poister and DeGuelle (2005) have failed to confirm a relationship between sedimentation velocity and particle size distribution. Poister (1995) found that an increase in diatoms, as indicated by increases in particulate biogenic silica, led to an increase in the sedimentation rate of P. In 2005, Poister and DeGuelle determined that their lake of study, Trout Lake, seemed to have a higher export coefficient than surrounding lakes that had lower abundance of diatoms.

Thus, if the community composition affects sedimentation velocity and the community composition is variable within and among lakes, it appears that an understanding of the effect of community composition of plankton should lead to a better understanding of sedimentation dynamics.

Reynolds (1984) illustrated how turbulence, chemical conditions and grazing can all affect diatom abundance and hence overall P sedimentation. As well, morphological features of a lake may also influence the sedimentation of particles from a system. Mean depth, areal phosphorus load and flushing rate have been included in many of the main eutrophication models (Vollenwieder, 1968;

Dillon and Rigler, 1974). The thickness of the epilimnion can play a role in determining particle residence time in this layer as well. Mixing depth will increase with lake size and fetch (Hanna, 1990) and plankton biomass and composition, through their effect on light penetration, can decrease the mixing depth (Mazumder and Taylor, 1994). The thinner the mixed layer, the greater the fractional loss of material per unit of time at a constant sedimentation velocity. This variability in mixing depth may influence the community composition of the plankton and, in turn, influence the sedimentation rates and velocity of the community. In fact, my review of the literature found that sedimentation velocity showed a positive correlation with surface area in lakes where the surface area was < 25 km^2 (Pearson Correlation, $r = 0.39$) (Fig. 4). There was also a moderate positive correlation between sedimentation velocity and mixing depth in lakes with a mixing depth <50m (Pearson Correlation, $r=0.41$). Thus, it is conceivable that the phytoplankton community present in a system shifts to slower sinking algae when there is a decrease in the depth of the mixed layer.

Grazers have also been found to influence the sedimentation velocity of seston via affects on size-distribution. Mazumder *et al.* (1989) observed that in experimental enclosures without fish there was a decrease in TP due to an increase in phosphorus sedimentation velocity. Further study by Mazumder *et al.* (1992) found that when fish were removed from a system, large phytoplankton dominated due to a preference by the *Daphnia* in the system for pico- and nano- plankton. This led to a higher sedimentation velocity of the particulate pool. Grazing can also influence sedimentation velocity by packaging small particles as larger fecal pellets.

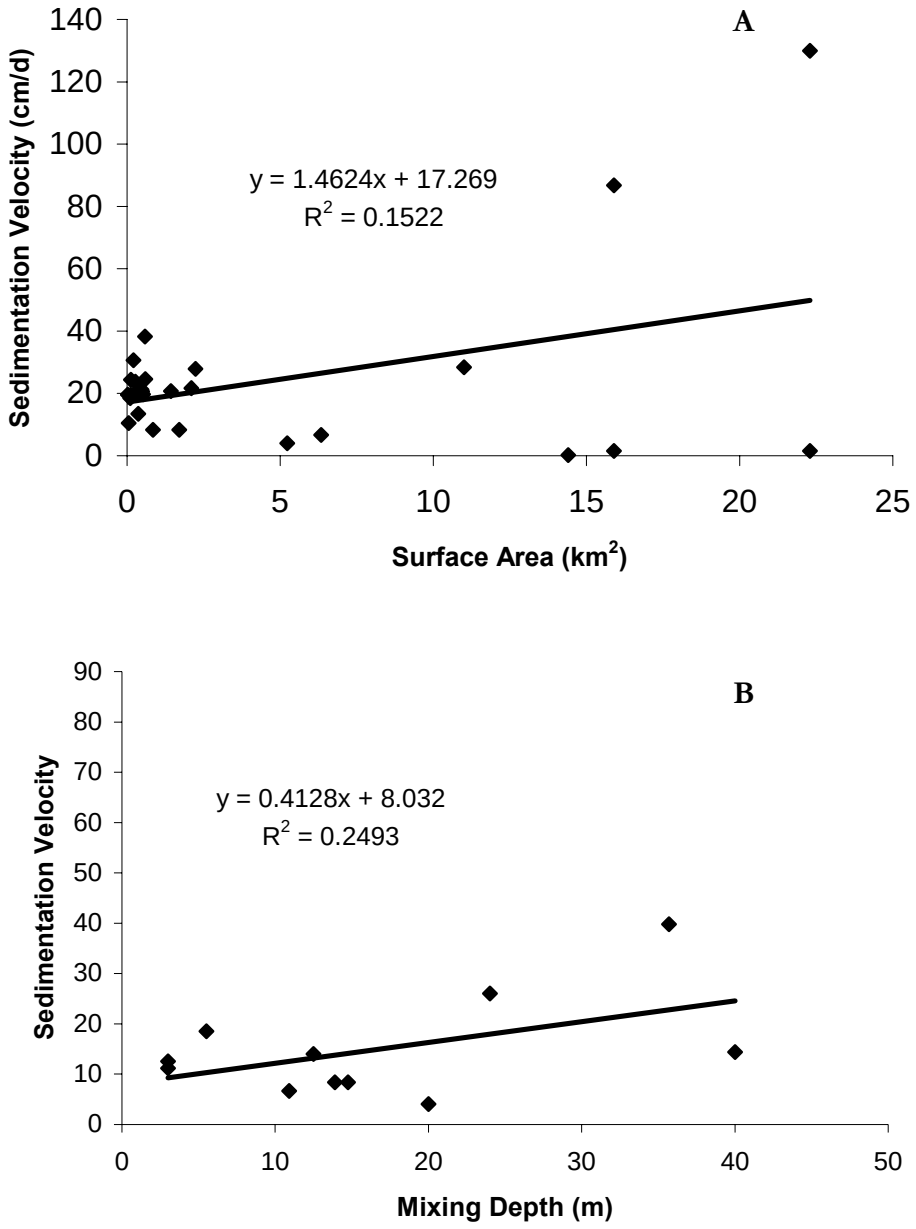


Figure 4 – Sedimentation velocity of phosphorus vs the morphological variables of A) surface area for 26 lakes and B) mixing depth for 9 lakes included in my unpublished review

What is clear is that plankton community composition is dynamic throughout the year, therefore a phosphorus sedimentation model that predicts sedimentation velocity from community composition would be useful for understanding the impact of changes in community composition on epilimnetic P concentration. This could be accomplished through a measure of the sedimentation velocity of dominant phytoplankton and other plankton particles as well as P. This model could then be applied to the management of phosphorus loading. It is the goal of this study to accomplish or contribute to this task.

Study Site

This study was conducted on the central and eastern basins of Lake Erie. There is a west to east depth gradient in Lake Erie, with a maximum depth of 10 m in the western basin and 60 m in the eastern basin. Due to the high incidence of sediment resuspension in the western basin, only the central and eastern basins were included in this study.

Historically, Lake Erie suffered the affects of severe eutrophication due to a population increase from 1910 to 1960 (UPHS, 1965). The increase in population led to a subsequent increase in the amount of waste dumped into tributaries. TP levels rose from 7.5 to 36 μg/L during this period (Chawla, 1971). Commercial fish species declined as a result while undesirable species such as the exotic alewife thrived.

In 1972, the Great Lakes Water Quality Agreement was created to outline and implement solutions to improve ecosystem health in all of the Great Lakes. TP

loading was to be reduced to 11 000 tons/year, or 10 μg/L over the whole volume of the lake (Dolan, 1993; Bertram, 1993). This was to be accomplished by reducing the amount of phosphate based detergents being discharged into the basin, increasing the level of treatment in sewage treatment plants and creating agricultural improvements such as no-till practices (Sweeny, 1993). Dolan and McGunagle (2005) have indeed reported a decrease in P load from 25 000 Tonnes/y in the late 1970's to 8 000-12 000 Tonnes/y at present. As predicted, as TP levels declined until 1995, so did chlorophyll (Rockwell *et al.*, 2005 and Charlton and Milne 2004). The introduction of dreissenid mussels into the lake in the early 1990's also led to a further 20% reduction of phytoplankton standing stock from 1995 levels (Nicholls *et al.*, 1999).

Despite the reduction in P load and the observed reduction of Chla, TP levels in the central and eastern basins seem to have been on the rise once again since 1995 (Rockwell *et al.*, 2005; Charlton and Milne, 2004). In fact, Rockwell *et al.* (2005) reported TP levels in spring 2002 as being the highest recorded since the 1970's. As well, hypolimnetic anoxia in the central basin is still occurring, even though the P models used in the initial Lake Erie management strategy predicted that a decline in P should have led to a decline in phytoplankton biomass and therefore a decline in oxygen depletion (Rockwell *et al.* 2005). This phenomenon has been deemed the "Lake Erie Trophic Paradox" by Matisoff and Ciborowski (2005).

Sedimentation dynamics are now being questioned as the source of this decoupling of chlorophyll and TP levels. DePinto *et al.* (2002), cited in Rockwell *et al.* (2005) hypothesized that the increase in TP may be due to a decrease in TP

sedimentation rate. Munawar and Munawar (1999) have indeed showed that phytoplankton particle size had decreased post 1995, which may explain a decrease in TP sedimentation rate.

Another possible cause of a decrease in TP sedimentation rate is the observed increase in soluble reactive silica (SRSi) in the central basin observed by Rockwell *et al.* (2005) and Barbeiro *et al.* (2005). This increase in SRSi could be caused by a decrease in the abundance of siliceous diatoms, whose high sedimentation velocities would contribute to a higher sedimentation rate. In fact, Barbeiro *et al.* (2005) noted that total phytoplankton biovolume has decreased to 20% of previous levels since 1996, considered the post-dreissenid period.

Of this reduced phytoplankton community Ghadouani and Smith (2006) have observed an increase in diatom abundance from 27-28% in 1978 (Munawar and Munawar, 1999) to 60-83% in 2002. In theory, this increase in abundance should be leading to an increase in the sedimentation rate of P, however it may not be sufficient enough to negate any substantial decrease in biovolume. Guildford *et al.* (2005) reported that diatoms in June comprised 80% of the total biomass and were dominated by *Stephanodiscus hantzshii*, *Actinocyclus normanii* and *Fragilaria crotonensis*. In July, the abundance of diatoms decreased substantially to compose just 22% of the total biomass but in September, percent biomass increased to 70% and the dominant species was *Fragilaria crotonensis*.

Further to a reduction in sedimentation rate of P, Conroy *et al.* (2005) hypothesized that internal loading may be an important source of P that may explain why reductions in external loads are not resulting in a reduction in

eutrophication effects. These internal loads may be P mineralized from the sediments during anoxic events or remineralized by the dreissenid population.

Objectives

The goal of my study was to examine the seasonal sedimentation dynamics of P in Lake Erie. More specifically:

1) To determine which phytoplankton species contribute most to P loss through sedimentation by estimating sedimentation velocities of major taxa. I hypothesize that large cells will have higher velocities than small ones, and that diatoms, having siliceous frustules, will have higher sedimentation velocities than other algae of comparable size.
2) To compare sedimentation of phosphorus to changes in TP during stratification. In particular to determine if sedimentation will be greater than or equal to the decline in TP from the epilimnion during periods of stratification. I hypothesize that this will indeed be the case and any difference will estimate the net transfer of P from the littoral zone plus areal deposition.
3) To compare the sedimentation velocities of different elements, including P, nitrogen (N), carbon (C), and silica (Si) as well as chlorophyll to evaluate how sedimentation affects plankton stoichiometry as well as to investigate the role of living versus dead phytoplankton and empty diatom frustules.
4) To compare the results of laboratory experiments using sedimentation towers with sediment trap data. I expect that towers will generally show lower sedimentation rates for all particles, as particles with negative sinking

rates will be included. However, I hypothesize that there will be a strong correlation between the two methods.

Materials and Methods

Study Site

To complete the objectives of this study, two stations were sampled from May to October of 2004. Station 84 is located in the central basin (41° 56', 81° 39') at a depth of 21 m and station 452 is located in the eastern basin (42° 35', 79° 55') at a depth of 60m (Fig. 5). The central basin was stratified from May to September while the eastern basin was stratified from May to October.

At both stations, sediment traps were deployed April 13th, 2004, to measure sedimentation rate and velocity. These sediment traps were made of clear PVC tubing 106 cm in length and 7 cm in diameter. The aspect ratio of the traps was 15:1 in accordance with Burns and Rosa's (1980) recommendations. Attached to the bottom of each cylinder was a 475-mL polyethylene cup. The traps were suspended from an aluminum frame in 5 replicates at depths of 18 m and 21 m at station 84 and at 20 m, 30 m, 40 m and 50.7 m at station 452. The aluminum frames were attached to a cable running from an anchor at the lake bottom to a subsurface float, all of which was attached to a surface buoy (Lean et al., 1987). Both stations were visited eight times from May to October 2004. All sampling was conducted aboard a Canadian Coast Guard vessel, the LIMNOS.

On each sampling date, temperature, oxygen and light profiles were taken. 20-L integrated water sample to the depth of the epilimnion was collected via a tube sampler and placed into a 20-L opaque polyethylene container. Discrete water samples were also taken at each station at the depths of each sediment trap using a Rosette sampler. This water was transferred to separate 20-L opaque polyethylene containers for each depth. Whenever possible, discrete water

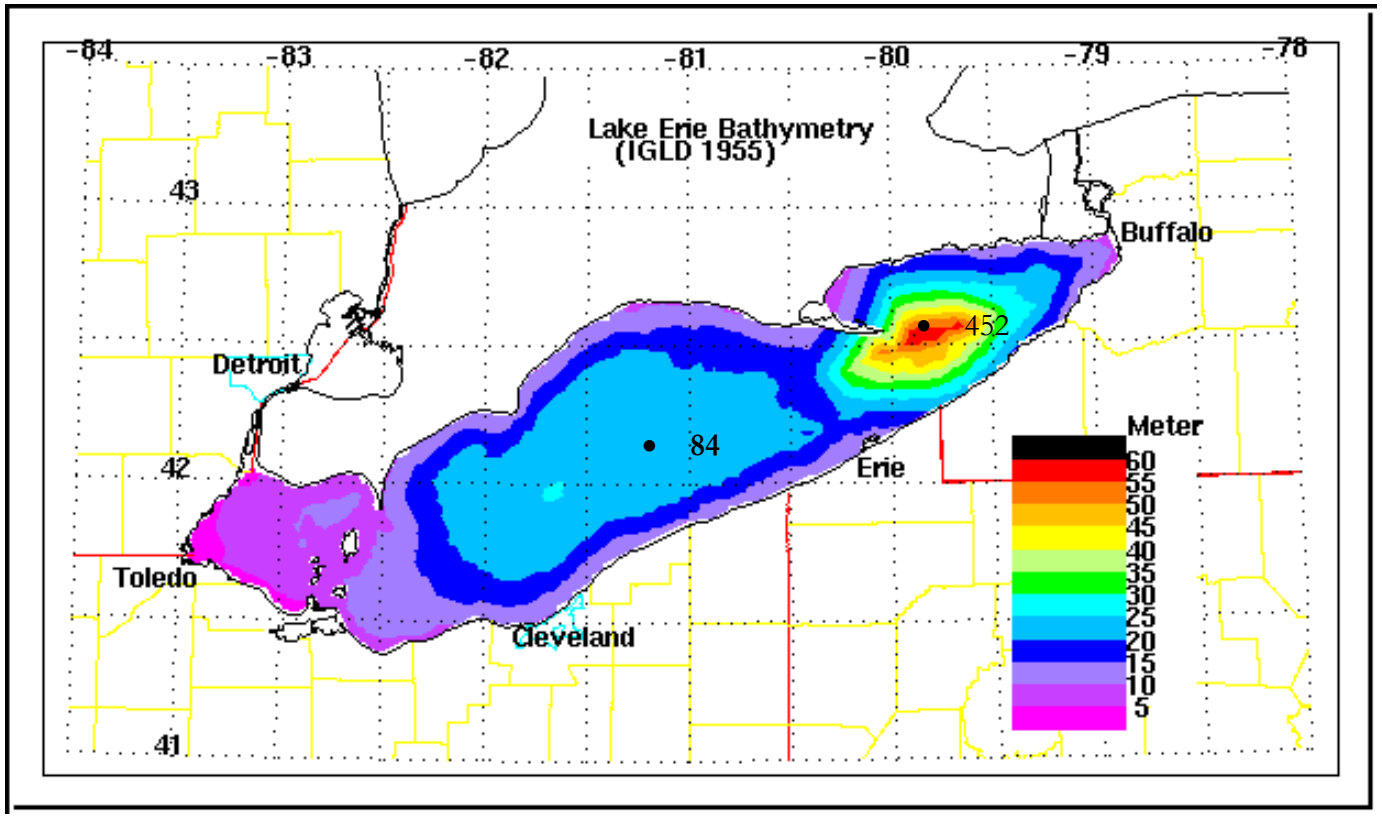


Figure 5 – Bathymetry map of Lake Erie (Schwab and Sellers, 1996)

samples were collected at each trap depth at least once in between trap sampling dates for nutrient analysis and phytoplankton counts.

Sediment trap material was collected on five occasions at station 84 and on three occasions at station 452. Upon retrieval, the overlaying water in the tubes was siphoned off leaving the sediment slurry in the attached cups. The cups were removed and replaced with new ones before redeployment of the traps. From the five cups collected at each depth, 90 mL was subsampled from each of three cups into three 100 mL polyethylene Nalgene containers, which were then frozen. 10 mL of slurry was also subsampled from each of three of the cups and placed into three 20-mL glass scintillation vials with 1 % Lugol's Iodine solution for microscopic analysis.

Water and Sediment Chemistry

For determination of TP in the epilimnion, 100 mL of the integrated epilimnetic water was placed in a 100-mL square glass bottle. The samples were stored at room temperature until analysis. TP samples were first digested with potassium persulphate in a boiling water bath (Menzel and Corwin, 1965; Wetzel and Likens, 1991). The TP concentration was then determined colourimetrically using the molybdenum blue method of Strickland and Parsons (1968). This method has an operating range of 1-500 μgP/L and a detection limit of 0.35 μg/L. Distilled water samples were run throughout the procedure as well as a standard curve of 0-150 μg/L for quality control monitoring.

Particulate P concentrations of the discrete water samples taken at each trap depth were prepared by vacuum filtering 500 mL of water onto a 0.8-μm

GF/F filter in triplicate. This GF/F filter was then placed in a 50-mL screw capped glass test tube and stored at room temperature.

In the lab, 35 mL of deionized water was placed in each tube and the filter and deionized water were digested in a water bath using potassium persulphate (Menzel and Corwin, 1965; Wetzel and Likens, 1991). The colourmetric determination of the P concentrations was then completed which has the same operating range and detection limits as TP (Strickland and Parsons, 1968). In this case, blank samples consisted of GF/F filters that had 500 mL distilled water filtered through them.

To determine the P concentration of the sediment trap material, 3.5 mL of sample thawed and resuspended. It was diluted to 35 mL with deionized water in a 50 mL glass screw capped test tube. The samples were persulphate digested in a boiling water bath (Menzel and Corwin, 1965; Wetzel and Likens, 1991) and analyzed colourmetrically using the ammonium molybdate method of Strickland and Parsons (1968).

Particulate C and N analysis consisted of vacuum filtering 500 mL of of water from each trap depth triplicate onto 0.8 μm GF/F filters. These samples were then frozen until later analysis in the Department of Biology at the University of Waterloo, using a CHN/O/S Elemental Analyzer Model CE 440 with a PC Compatible/CE-490 Interface Unit. Samples were first digested using 10% HCl acid and when analyzed, corrected to an acetanilide standard (Ehrhardt, 1983). The error associated with this analysis for both elements was ± 0.3%. Blank filters with 500 mL of distilled water filtered through them were run through out as a quality control measure.

To measure the C and N concentration in the sediment trap material, 5-15 mL of the material was placed into a 20-mL glass scintillation vial and freeze-dried in a ModulyoD ThermoSavant freeze dryer. The dried sample was then placed in a nickel capsule and analyzed in the CHN/O/S Elemental Analyzer Model CE 440 as was done for the filtered samples.

To determine the "chlorophyll" (chlorophyll a and pheophytin) concentrations in the discrete water samples at each depth, 500 mL aliquots were vacuum filtered onto a 0.8 μm GF/F filter in triplicate and then frozen until analysis. They were then extracted using 90% acetone for 24 h after which the chlorophyll concentrations were determined fluorometrically (Parsons and Strickland, 1963; SCOR/UNESCO, 1966; Stainton et al., 1977). Filters with 500 mL of distilled water filtered through them were used as blanks for quality control purposes.

Two mL of material from the sediment traps was placed into a 20-mL glass scintillation vial with 18 mL of acetone for extraction. This was done in triplicate. Following 24 h extraction, the samples were then analyzed fluorometrically for chlorophyll (Parsons and Strickland, 1963; SCOR/UNESCO, 1966; Stainton et al., 1977).

In order to determine particulate biogenic Si, 50 mL of discrete water at each trap depth was vacuum filtered onto 0.22-μm polycarbonate filters in triplicate. The filters were then frozen until later analysis. In the lab, the filters were digested in 0.2 N NaOH at 105°C in an autoclave (Stainton et al., 1977). Concentrations were then measured using the ammonium molybdate method of Strickland (1952). This method has an operating range of 5-2000 μgSi/L and blank

GF/F filters were run through out the experiment (blank filters having 50 mL of distilled water filtered through them). A standard set of concentrations from 0-2000 μgSi/L was also measured.

0.1 mL of sediment trap sample was placed in 8 mL of distilled water. The samples were then digested with 0.2 M NaOH at 105°C. After digestion the particulate silica concentrations were determined by the ammonium molybdate method (Stainton et al, 1977; and Strickland, 1952).

In order to determine if calcite precipitation had occurred in either basin during 2004, sediment material was analyzed for calcium (Ca). 5 mL of sediment trap contents was vacuum filtered onto a 0.8 μm GF/F filter in triplicate. These were then digested in 20 mL of distilled water and adjusted to a pH of 4 using HCl. Samples were then analyzed using an ion chromatography in the Department of Engineering, Faculty of Chemical Engineering at the University of Waterloo. All concentrations were blank corrected with GF/F filters that had had distilled water filtered onto them in lieu of sediment trap material.

Phytoplankton abundance

For each trap depth, 1 L of whole water was preserved with 1% Lugol's solution and microscopic counts were performed on a Ziess Axiovert35 inverted microscope using the Utermöhl technique (Lund *et al.*, 1958). At least two hundred cells were counted in total at 400x magnification. For infrequent species half of the chamber was counted at 100x magnification.

For the purpose of this study, centric diatom spp. denotes any non-colonial centric diatom while "large centric diatom" spp. are those centric spp. greater than

1000 μm^3. "Other colonial diatom" spp. includes all colonial diatoms other than *Aulacoseira* sp. *Gymnodinium* spp. includes all species except *Gymnodinium helveticum*. "Green colonial" spp. includes all colonial green species with the exception of *Oocystis* sp. while Dinoflagellate spp. does not include *Ceratium hiriundinella*, *Gymnodinium helviticum* or *Gymnodinium* spp. or *Peridinium* sp.

Determination of Sedimentation Rate and Velocity from Sediment Traps

Sedimentation rate (mg/m^2d) of the SPM was calculated by multiplying the average concentration in the traps of each component by the volume of sedimenting material collected in the trap (475 mL). This was then divided by the area of the mouth of the trap (0.003848 m^2) and multiplied by the deployment period in days. Phytoplankton sedimentation (mg C/m^2d) was calculated as above, however, the concentration of $cells/m^2d$ was first converted to carbon biomass ($\mu g/L$) using the following equations:

(1) Total phytoplankton biovolume ($\mu m^3/L$) = (average phytoplankton concentration (cells/L) x average individual cell biovolume (μm^3)

(2) Carbon Biomass ($\mu g/L$) = total phytoplankton biovolume ($\mu m^3/L$) x conversion factor (0.22 for cyanobacteria, 0.13 for thecate dinoflagellates, 0.16 for chlorophytes and 0.11 for diatoms and all other species) (Hiriart-Baer, 2003)

Sedimentation velocity (cm/d) of the sediment components and phytoplankton was determined by dividing the sedimentation rate of each by the average concentration found in the discrete water samples taken at each trap depth.

In Laboratory Determination of Sedimentation Velocity

For each station on each sampling date, 4 L of integrated epilimnetic water was poured into a sedimentation tower. The towers were made of clear PVC tubing, 1 m in height and 4.27 cm in internal diameter. Each experiment was done in triplicate. Once the water was placed in the tower it was covered to keep the system in the dark and allowed to sit for 1 hour at room temperature. It was experimentally determined that an incubation period of any longer led to many of the species completely sedimenting out of the system. After the incubation period, the top half of the water in each tower was siphoned off and subsampled for P, C, N, Si, chlorophyll and microscopic analysis using the procedures mentioned earlier. The same was done for the remaining water in the bottoms of the towers.

Once the nutrient and algal concentrations were determined for each half of water in the towers, the original concentration, sedimentation rate and sedimentation velocity of each was calculated using the following equations from Burns and Rosa (1980).

1) $C_i = (V_tC_t + V_bC_b)/(V_t + V_b)$

Where C_i = the initial concentration of the particle or nutrient Vt = the volume in the top section, C_t = the final concentration in the top section, V_b = the volume of the bottom section and C_b = the final concentration of the bottom section.

2) $f = V_b(C_b - C_i)$

Where f = the net transport from the top section to the bottom section of the tower or sedimentation rate.

3) $S = F/C_i$

Where S = the net settling velocity, F = f/(cross sectional area) x settling time)

Data Analysis

All statistical analysis was performed using Microsoft Excel, 2000. To determine if any significant difference in sedimentation rate or sedimentation velocity existed between the two basins, a two-sample t-test assuming equal variances was completed for all sediment components and seven of the phytoplankton groups (Samuels and Witmer, 1999). These groups included the centric diatom spp., "large centric diatom" spp., *Aulacoseira* sp., *Asterionella* sp., *Synedra* sp., *Fragilaria* sp. as well as the ciliophora. These groups were chosen for statistical analysis since they were the most abundant groups that were generally present in the sediment traps at all sampling dates. To determine if the variances at the two sites were equal, an F-test was performed and if necessary, the data was log transformed (Samuels and Witmer, 1999). In the case of P, C and Si sedimentation rate along with Si, *Asterionella* sp. and *Synedra* sp. sedimentation velocity unequal variances were observed and thus the data was log transformed.

Paired t-tests were completed to compare the sedimentation rates and sedimentation velocities of the sediment components to one another. This was also carried out for the select phytoplankton groups (Samuels and Witmer, 1999). In the case of the centric diatom spp. vs. *Asterionella* sp. and *Fragilaria* sp. as well as *Asterionella* sp. vs. *Synedra* sp. and *Fragilaria* sp. F-tests revealed unequal variances and thus the data was log transformed.

Scatterplots were also created to examine the relationship between sedimentation rates of each sediment component with one another as well as the

sedimentation velocities. Pearson correlations were used to determine if any of these relationships were significant (Price, 2000).

For both the sediment components and selected phytoplankton groups, ANOVA's were preformed to determine if any significant differences existed for both sedimentation rate and velocity among the dates of sampling (Samuels and Witmer, 1999). ANOVA's were also completed to determine any difference with depth of traps. The Taylor Power law was used to determine if any of the data sets required transformation (Bolker, 2001). In fact all data required log transformation with the exception of P sedimentation rate by date at station 84, Si sedimentation velocity by date at station 84, N and Si sedimentation velocity by depth at station 84, C sedimentation velocity by date at station 452 and C sedimentation velocity by depth at station 452.

In order to determine if a relationship existed between cell size and sedimentation velocity a scatterplot was created. Cell size was measured for algal cells of various shapes as equivalent spherical diameter to facilitate comparison. 2 outliers were removed, both belonging to "large centric diatom" spp. with sedimentation velocities of 466742.000 cm/d and 428898.770 cm/d. The significance of the correlation was determined using the Pearson correlation (Price, 2000). Correlation analysis was also used to examine the relationship between temperature and sedimentation velocity of the phytoplankton as well as compare the sedimentation velocities calculated via the tower method for the phytoplankton community with those calculated via the trap method. Again, significance was determined using a Pearson correlation (Price, 2000).

Results

Temperature Profiles

Thermal stratification had already occurred by the first sampling trip at the end of May for both stations 84 and 452 (Fig. 6). It continued until late August at station 84, and right through to the last sampling trip at the beginning of October for Station 452.

Phytoplankton Sedimentation

The sedimentation rates of many of the phytoplankton species sampled were relatively low (Table 1). *Fragilaria sp.* was found to have the highest sedimentation rate at both station 84 (1695.27 mgC/m^2d) and station 452 (446.76 mgC/m^2d). "Large centric diatom" spp. contributed to the second highest sedimentation rates at both stations with 191.72 mgC/m^2d at station 84 and 49.75 mgC/m^2d at station 452. At station 84 the algal group with the third highest sedimentation rate was the "other colonial centric diatom" spp. with 74.36 mgC/m^2d while at station 452 the third highest sedimentation rate was the "centric diatom" spp. with 14.19 mgC/m^2d.

Seven taxa with the highest counts were selected for statistical analysis. These included the "centric diatom" spp., "large centric diatom" spp., *Aulacoseira* spp., *Asterionella* spp., ciliates, *Synedra* spp. and *Fragilaria* spp. A significant difference in sedimentation rate was found between station 84 and station 452 for the large centric diatoms, *Asterionella* spp. and *Fragilaria* spp. (t-test, $P=0.04$, $P=0.02$ and $P=0.03$ respectively). There was no significant difference in sedimentation rate between stations for the remaining four taxa.

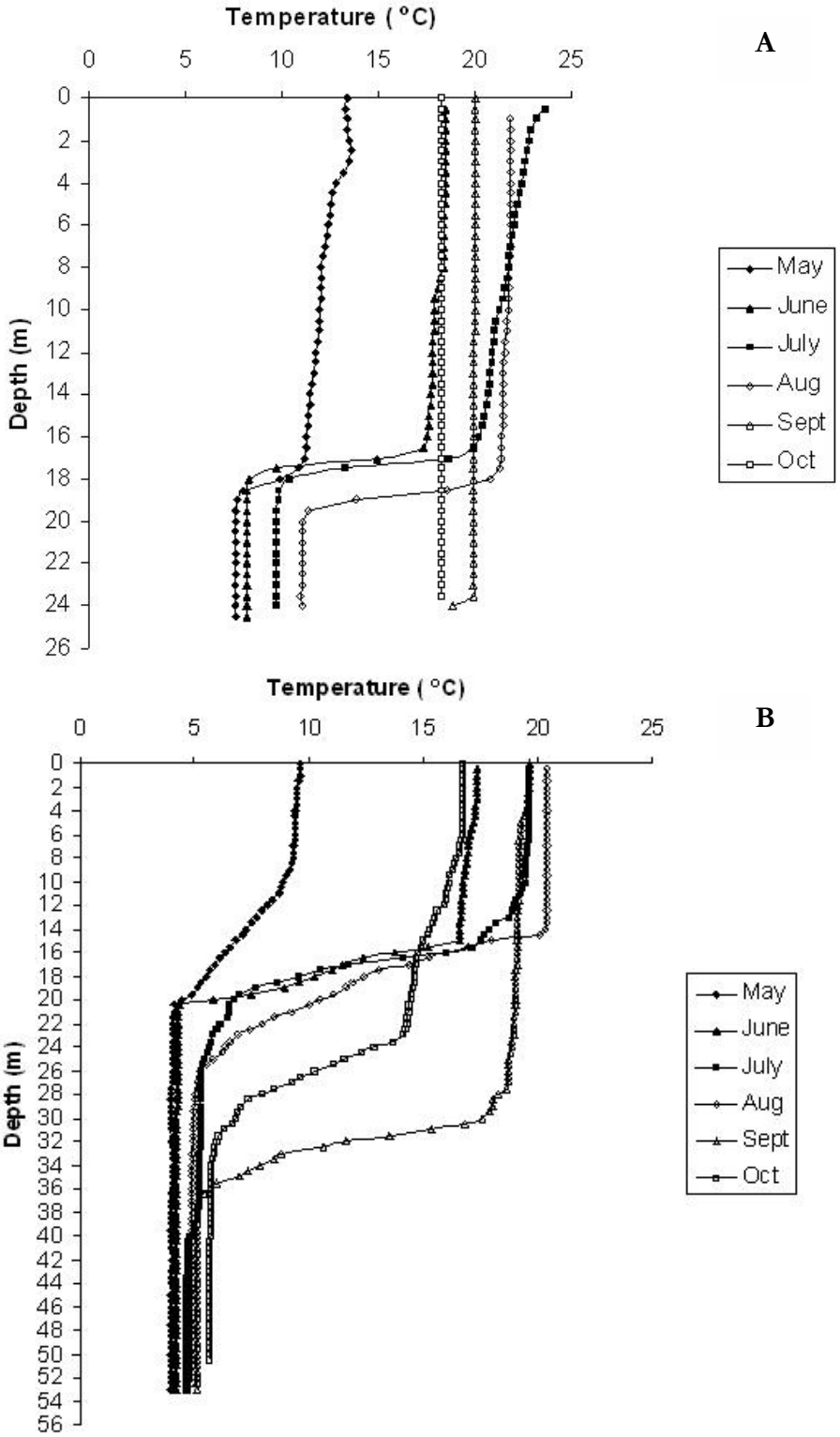


Figure 6 – Temperature profiles for Lake Erie's central basin at station 84 (a) and eastern basin at station 452(b) for the sampling period of May – October 2004

Table 1 – Phytoplankton sedimentation rates (mg C/m^2d) for Lake Erie's central (station 84) and eastern (station 452) basins, measured by sedimentation traps deployed from April to October 2004.

Station	Date Sampled	Depth (m)	Centric Diatom sp.	"Large Centric Diatoms" sp.	*Aulacoseira* sp.	Dinoflagellate *spp.*	*Plageoselmis nanoplanctica*	*Asterionella* sp.
84	2-Jun-04	18	3.468	351.360	12.504	0.000	0.000	20.335
84	21-Jul-04	18	1.825	47.481	0.132	0.000	0.000	8.897
84	26-Aug-04	18	0.086	0.542	0.002	0.000	0.000	0.010
84	6-Oct-04	18	2.705	141.864	2.077	0.000	0.000	0.042
84	2-Jun-04	21	2.409	645.743	16.709	0.000	0.000	34.316
84	21-Jul-04	21	2.519	128.199	2.523	0.000	0.000	17.158
84	26-Aug-04	21	0.123	9.663	0.184	0.000	0.000	0.051
84	6-Oct-04	21	3.943	208.917	2.579	0.000	0.000	0.051
452	2-Jun-04	20	35.921	85.466	3.028	0.841	0.341	0.796
452	5-Aug-04	20	0.405	0.174	0.091	0.004	0.000	0.255
452	7-Oct-04	20	2.124	61.800	0.000	0.000	0.000	0.070
452	2-Jun-04	30	53.188	175.680	2.355	0.000	0.000	2.786
452	5-Aug-04	30	0.931	1.487	0.057	0.000	0.000	3.134
452	7-Oct-04	30	1.022	13.380	0.000	0.000	0.000	0.051
452	2-Jun-04	40	30.555	137.695	2.579	0.000	0.000	1.194
452	5-Aug-04	40	0.621	0.228	0.016	0.000	0.000	0.310
452	7-Oct-04	40	0.876	16.353	0.000	0.000	0.000	0.162
452	2-Jun-04	50.7	43.076	104.458	1.178	0.000	0.000	1.094
452	5-Aug-04	50	0.785	0.000	0.070	0.000	0.000	1.791
452	7-Oct-04	50.7	0.767	0.265	0.009	0.000	0.000	0.162
Average Station 84			**2.135**	**191.721**	**4.589**	**0.000**	**0.000**	**10.108**
Average Station 452			**14.189**	**49.749**	**0.782**	**0.070**	**0.028**	**0.984**

Table 1 continued…

Station	Date Sampled	Depth (m)	"Other Colonial Centric Diatom" spp.	Ciliate spp.	*Diatoma sp.*	Rotifer Eggs	*Synedra sp.*	Cryptomonad spp.	*Dinobryon sp.*	*Gymnodinium helviticum*
84	2-Jun-04	18	260.622	0.000	0.300	0.000	0.000	0.000	0.000	0.000
84	21-Jul-04	18	0.983	0.000	0.215	0.000	7.042	0.000	0.000	0.000
84	26-Aug-04	18	0.000	0.209	0.000	0.000	0.001	0.002	0.000	0.000
84	6-Oct-04	18	3.693	0.213	0.005	0.207	0.371	0.000	0.000	0.000
84	2-Jun-04	21	324.768	0.000	0.000	0.000	0.000	0.000	0.000	0.000
84	21-Jul-04	21	4.775	0.000	0.000	0.000	11.307	0.000	0.046	0.000
84	26-Aug-04	21	0.000	0.138	0.000	0.000	0.004	0.001	0.000	0.000
84	6-Oct-04	21	0.000	0.356	0.000	0.000	0.070	0.000	0.000	0.000
452	2-Jun-04	20	15.252	1.903	0.215	3.399	0.000	0.000	0.000	0.000
452	5-Aug-04	20	0.000	0.588	0.920	0.133	0.113	0.009	0.007	0.000
452	7-Oct-04	20	0.000	0.037	0.000	0.000	0.011	0.000	0.000	0.000
452	2-Jun-04	30	16.597	1.268	1.330	0.000	0.047	4.984	2.945	0.000
452	5-Aug-04	30	0.000	1.744	2.878	1.214	0.744	0.000	0.000	0.000
452	7-Oct-04	30	0.000	0.194	0.000	0.347	0.012	0.000	0.000	0.000
452	2-Jun-04	40	0.000	0.000	0.000	0.000	0.000	4.984	0.000	0.488
452	5-Aug-04	40	0.029	0.235	0.730	0.433	0.140	0.002	0.007	0.000
452	7-Oct-04	40	0.000	0.113	0.000	0.000	0.013	0.000	0.000	0.000
452	2-Jun-04	50.7	13.906	0.000	0.901	0.000	0.000	0.000	0.161	0.000
452	5-Aug-04	50	0.000	0.655	3.975	0.000	0.217	0.000	0.002	0.000
452	7-Oct-04	50.7	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000
Average station 84			**74.355**	**0.114**	**0.065**	**0.026**	**2.349**	**0.000**	**0.006**	**0.000**
Average station 452			**3.815**	**0.561**	**0.912**	**0.460**	**0.108**	**0.832**	**0.260**	**0.041**

Table 1 continued…

Station	Date Sampled	Depth (m)	*Fragilaria* sp.	*Gymnodinium* sp.	*Pediastrum* sp.	*Anabena* sp.	Pollen	*Ceratium hirundinella*	Colonial Green spp.	*Peridinium* sp.
84	2-Jun-04	18	967.623	0.000	0.000	0.000	0.000	0.000	0.000	0.000
84	21-Jul-04	18	1667.606	0.020	0.000	0.000	0.000	0.000	0.000	0.000
84	26-Aug-04	18	99.801	0.000	0.000	0.000	0.000	0.000	0.998	0.000
84	6-Oct-04	18	1500.896	0.000	8.175	0.000	0.373	0.000	0.000	0.000
84	2-Jun-04	21	2573.466	0.000	0.000	0.000	0.000	0.000	0.000	0.000
84	21-Jul-04	21	5476.336	0.000	19.152	0.000	0.000	0.000	0.000	0.000
84	26-Aug-04	21	205.877	0.000	0.977	0.000	0.117	0.000	0.733	0.000
84	6-Oct-04	21	1070.562	0.000	7.817	0.024	0.000	0.000	1.710	0.000
452	2-Jun-04	20	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
452	5-Aug-04	20	575.331	0.013	0.000	0.004	0.209	0.027	0.234	0.000
452	7-Oct-04	20	843.293	0.000	0.748	0.004	0.120	0.000	1.590	0.000
452	2-Jun-04	30	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
452	5-Aug-04	30	1425.700	0.761	0.000	0.016	0.468	0.018	0.244	7.552
452	7-Oct-04	30	782.334	0.000	0.000	0.000	0.000	0.000	0.611	0.000
452	2-Jun-04	40	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
452	5-Aug-04	40	437.489	0.024	0.000	0.548	0.078	0.000	0.061	0.084
452	7-Oct-04	40	442.636	0.000	3.909	0.000	0.000	0.000	35.910	0.000
452	2-Jun-04	50.7	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
452	5-Aug-04	50	638.220	0.149	0.000	0.005	0.507	0.000	0.061	0.084
452	7-Oct-04	50.7	216.171	0.000	0.977	0.000	0.000	0.000	2.199	0.000
Average Station 84			**1695.271**	**0.002**	**4.515**	**0.003**	**0.061**	**0.000**	**0.430**	**0.000**
Average Station 452			**446.764**	**0.079**	**0.469**	**0.048**	**0.115**	**0.004**	**3.409**	**0.643**

Table 1 continued…

Station	Date Sampled	Depth (m)	*Choanoflagellate* sp.	*Staurastrum* sp.	*Staurodesmus* sp.	*Oocystis* sp.	Colonial Rod Cyanobacteria	*Tabellaria* sp.	*Microcystis* sp.
84	2-Jun-04	18	0.000	0.000	0.000	0.000	0.000	0.000	0.000
84	21-Jul-04	18	0.000	0.000	0.000	0.000	0.000	0.000	0.000
84	26-Aug-04	18	0.000	0.333	0.000	0.788	3.658	0.065	0.000
84	6-Oct-04	18	0.000	7.007	0.000	2.076	0.000	0.764	0.000
84	2-Jun-04	21	0.000	0.000	0.000	0.000	0.000	0.000	0.000
84	21-Jul-04	21	0.000	0.000	0.000	0.000	0.000	0.000	0.000
84	26-Aug-04	21	0.000	0.733	0.000	0.000	0.000	0.591	0.000
84	6-Oct-04	21	0.000	4.886	0.000	0.000	0.000	0.447	0.000
452	2-Jun-04	20	0.000	0.000	0.000	0.000	0.000	0.000	0.000
452	5-Aug-04	20	0.000	0.000	0.000	0.000	0.000	0.000	0.000
452	7-Oct-04	20	0.000	1.870	0.135	0.000	0.000	0.000	10.287
452	2-Jun-04	30	0.000	0.000	0.000	0.000	0.000	0.000	0.000
452	5-Aug-04	30	0.301	0.489	0.000	0.000	0.000	0.000	0.000
452	7-Oct-04	30	0.000	0.977	0.000	0.000	0.000	0.000	1.344
452	2-Jun-04	40	0.000	0.000	0.000	0.000	0.000	0.000	0.000
452	5-Aug-04	40	0.000	0.000	0.088	0.000	0.000	0.000	0.000
452	7-Oct-04	40	0.000	0.977	0.088	0.000	2.687	0.000	18.810
452	2-Jun-04	50.7	0.000	0.000	0.000	0.000	0.000	0.000	0.000
452	5-Aug-04	50	0.000	0.000	0.000	0.000	0.000	0.000	0.000
452	7-Oct-04	50.7	0.000	2.443	0.000	0.000	10.749	0.000	0.000
Average Station 84			**0.000**	**1.620**	**0.000**	**0.358**	**0.457**	**0.233**	**0.000**
Average Station 452			**0.025**	**0.563**	**0.026**	**0.000**	**1.120**	**0.000**	**2.537**

Paired t-tests comparing the sedimentation rates of the taxa with each other showed that there were significant differences in average sedimentation rate among the majority of the taxa. Sedimentation rate did differ significantly by date for all species tested with the exception of the ciliates at station 452, while no significant differences were found in sedimentation rate with sampling depth.

The phytoplankton sedimentation rates were highly variable when measured in the laboratory sedimentation towers and again, negative sedimentation rates were recorded (Table 2). At station 84 *Fragilaria* spp. was found to have the highest sedimentation rate, agreeing with the sedimentation trap measurements. However, this was not the case for station 452 where *Rhodomonas lens* was found to have the highest sedimentation rate.

The algal sedimentation velocities were highly variable (Table 3). At station 84, "large centric diatom" spp. had the highest sedimentation velocity of 149781 cm/d, followed by "other colonial centric diatom" spp. (16605 cm/d) and *Aulacoseira* sp. (3787 cm/d). The same three species had the highest sedimentation velocities at station 452, although the "other colonial centric diatom" spp. had the greatest sedimentation velocity at 10855.89 cm/d, "large centric diatom" spp. had the second greatest (4673 cm/d) and finally *Aulacoseira* sp. had the third greatest at 1153 cm/d.

The seven taxa selected for statistical analysis of sedimentation rate were used also to look at sedimentation trends. For all seven taxa there was no

Table 2 – Phytoplankton sedimentation rates (mg C/m^{2}d) for Lake Erie, April – October 2004, central (84) and eastern (452) basins measured in the specially constructed in laboratory sedimentation towers.

Station	Date	Depth (m)	*Plageoselmis nanoplanctica*	*Rhodamonas lens*	Centric Diatom spp.	Heteroflagellate spp.	Nanoflagellate spp.	*Dinobryon* sp.	Small Cryptomonad spp.
84	24-Jun-04	0-18	-0.440	0.000	40.192	-0.419	-0.062	17.145	-2.351
84	21-Jul-04	0-16	-0.001	0.000	0.012	0.000	-0.023	-0.003	0.006
452	22-Jun-04	0-15	0.000	0.000	-0.773	-1.676	1.200	4.676	-2.992
452	20-Jul-04	0-10	0.255	15.277	-0.105	0.217	0.523	0.098	0.128
Average Station 84			**-0.220**	**-**	**20.102**	**-0.419**	**-0.042**	**8.571**	**-1.172**
Average Station 452			**0.255**	**15.277**	**-0.439**	**-0.729**	**0.862**	**2.387**	**-1.432**

Station	Date	Depth (m)	Large Cryptomonad spp.	*Chrysochromulina* sp.	Ciliate spp.	*Asterionella* sp.	*Synedra* sp.	*Fragilaria* sp.	*Ceratium hirundinella*	*Monoriphidium* sp.
84	24-Jun-04	0-18	0.000	0.033	-5.824	0.107	0.201	315.964	0.371	0.000
84	21-Jul-04	0-16	0.000	0.000	-0.061	-0.002	0.000	71.571	0.000	0.000
452	22-Jun-04	0-15	0.000	-0.264	0.856	1.021	0.134	-26.113	0.000	0.050
452	20-Jul-04	0-10	-0.620	-0.071	-66.012	0.111	0.000	-10131.509	0.321	0.000
Average Station 84			**0.000**	**0.033**	**-2.942**	**0.053**	**0.101**	**193.768**	**0.186**	**0.000**
Average Station 452			**-0.620**	**-0.167**	**-32.578**	**0.566**	**0.067**	**-5078.811**	**0.321**	**0.050**

Table 2 continued…

Station	Date	Depth (m)	*Gymnodinium* spp.	"Large" *Gymnodinium* spp.	*Diatoma* sp.	"Large" *Synedra* sp.	*Anabena* sp.	Green Algae spp.	*Peridinium* sp.
84	24-Jun-04	0-18	0.000	0.000	0.000	0.000	0.000	0.000	0.000
84	21-Jul-04	0-16	0.000	0.000	0.000	0.000	0.005	0.109	8.000
452	22-Jun-04	0-15	0.000	0.000	2.295	0.176	0.000	0.000	0.000
452	20-Jul-04	0-10	0.087	0.031	0.000	0.000	0.065	13.716	-0.001
Average Station 84			**0.000**	**0.000**	**0.000**	**0.000**	**0.005**	**0.109**	**0.011**
Average Station 452			**0.087**	**0.031**	**2.295**	**0.176**	**0.065**	**13.716**	**-0.001**

Table 3 – Phytoplankton sedimentation velocities (cm/d) calculated for Lake Erie from sedimentation traps deployed in the eastern (station 452) and central (station 84) basins, April – October 2004. Values represent an average of three replicate samples.

Station	Date Sampled	Depth (m)	Centric Diatom spp.	"Large Centric Diatom" spp.	*Aulacoseira* sp.	Dinoflagellate spp.	*Plageoselmis nanoplanctica*	*Asterionella* sp.
84	2-Jun-04	18		466742.784				420.489
84	21-Jul-04	18	13.840	151.838	477.779			15.920
84	26-Aug-04	18	0.324	239.996			0.013	
84	6-Oct-04	18						25.189
84	2-Jun-04	21		428898.775	8032.418			756.880
84	21-Jul-04	21	43.451	2301.325	6600.699			43.013
84	26-Aug-04	21	2.198	349.434	37.894			0.063
84	6-Oct-04	21						27.988
452	2-Jun-04	20	371.453	4204.890	2961.705	79.166	8.920	65.827
452	5-Aug-04	20	52.432			0.264		1.572
452	7-Oct-04	20	77.141	13682.318				21.696
452	2-Jun-04	30	732.012	7071.860	825.259			276.475
452	5-Aug-04	30	125.803					36.323
452	7-Oct-04	30						
452	2-Jun-04	40	426.642	8314.214	1312.839			148.112
452	5-Aug-04	40	590.132	57.856	211.175			49.707
452	7-Oct-04	40	5.260	307.994				
452	2-Jun-04	50.7	926.618	3750.307	697.126			102.467
452	5-Aug-04	50	310.976		907.183			658.439
452	7-Oct-04	50.7	4.050	0.216				
Average Station 84			**14.953**	**149780.692**	**3787.198**		**0.013**	**184.220**
Average Station 452			**329.320**	**4673.707**	**1152.548**	**39.715**	**8.920**	**151.180**

Table 3 continued…

Station	Date Sampled	Depth (m)	"Other Colonial Centric Diatom" spp	Ciliate spp.	*Diatoma* sp.	Rotifer Eggs	*Synedra* sp.	Cryptomonad spp.	*Dinobryon* sp.	*Gymnodinium helviticum*
84	2-Jun-04	18			987.410					
84	21-Jul-04	18					352.448			
84	26-Aug-04	18		0.622			8.571	0.040		
84	6-Oct-04	18		0.785		8.396	493.705			
84	2-Jun-04	21	16605.493							
84	21-Jul-04	21					524.079		1.753	
84	26-Aug-04	21		0.496			4.762	0.021		
84	6-Oct-04	21		1.663			61.573			
452	2-Jun-04	20		144.499	297.013					
452	5-Aug-04	20		2.427	50.624	2.314	4.376	0.162	27.226	
452	7-Oct-04	20		0.359			7.232			
452	2-Jun-04	30	17951.646	51.294	612.194		370.279	4541.281		
452	5-Aug-04	30		31.029	889.562	80.998	57.030			
452	7-Oct-04	30		115.712			96.427			
452	2-Jun-04	40						4204.890		47.020
452	5-Aug-04	40		16.449	196.711	32.142	52.607	0.918	115.712	
452	7-Oct-04	40		2.328						
452	5-Aug-04	50		117.159	1364.051		127.006			
452	2-Jun-04	50.7	3760.142		560.422					
452	5-Aug-04	50		117.159	1364.051		127.006			
452	7-Oct-04	50.7								
Average Station 84			**16605.493**	**0.892**	**987.410**	**8.396**	**240.856**	**0.031**	**1.753**	
Average Station 452			**10855.894**	**53.473**	**567.225**	**38.485**	**102.137**	**2186.813**	**71.469**	**47.020**

Table 3 continued…

Station	Date Sampled	Depth (m)	*Fragilaria* sp.	*Gymnodinium* sp.	*Pediastrum* sp.	*Anabena* sp.	Pollen	*Ceratium hirundinella*	Green Colonial spp.	*Peridinium* sp.
84	2-Jun-04	18	175.557							
84	21-Jul-04	18	234.829	1.938						
84	26-Aug-04	18	27.869							
84	6-Oct-04	18	133.537		176.323					
84	2-Jun-04	21	412.957							
84	21-Jul-04	21	561.308		987.410					
84	26-Aug-04	21	27.376		34.285					
84	6-Oct-04	21	105.910			4.141			0.529	
452	2-Jun-04	20								
452	5-Aug-04	20	25.792	4.706		3.952	202.496	28.928		
452	7-Oct-04	20	244.654			0.344			0.436	
452	2-Jun-04	30								
452	5-Aug-04	30	138.339	517.399		57.133	347.136	14.464		215.583
452	7-Oct-04	30	1444.914							
452	2-Jun-04	40								
452	5-Aug-04	40	194.818	50.356			38.571			16.875
452	7-Oct-04	40	56.959						3.774	
452	5-Aug-04	50	258.105	2126.211						
452	2-Jun-04	50.7								
452	7-Oct-04	50.7	78.394						0.347	
Average Station 84			**209.918**	**1.938**	**399.340**	**4.141**			**0.529**	
Average Station 452			**305.247**	**674.668**		**20.476**	**196.068**	**21.696**	**1.519**	**116.229**

Table 3 continued…

Station	Date Sampled	Depth (m)	*Staurastrum* sp.	*Staurodesmus* sp.	*Oocystis* sp.	"Colonial Rod Cyanobacteria" spp.	*Tabellaria* sp.	*Microcystis* sp.
84	2-Jun-04	18						
84	21-Jul-04	18						
84	26-Aug-04	18	11.428		0.274			
84	6-Oct-04	18			0.302			
84	2-Jun-04	21						
84	21-Jul-04	21						
84	26-Aug-04	21	51.428				7.506	
84	6-Oct-04	21						
452	2-Jun-04	20						
452	5-Aug-04	20						
452	7-Oct-04	20		0.016				0.385
452	2-Jun-04	30						
452	5-Aug-04	30						
452	7-Oct-04	30						1.071
452	2-Jun-04	40						
452	5-Aug-04	40						
452	7-Oct-04	40		0.459		0.154		0.216
452	5-Aug-04	50						
452	2-Jun-04	50.7						
452	7-Oct-04	50.7	32.142			0.616		
Average Station 84			**31.428**		**0.288**		**7.506**	
Average Station 452			**32.142**	**0.238**		**0.385**		**0.557**

significant difference in sedimentation velocity between stations 84 and 452. When the individual sedimentation velocities were compared with one another using a t-test, the average sedimentation velocity of *Aulacoseira* sp. was significantly different than all other species tested with the exception of the "large centric diatom" spp. As well, the sedimentation velocity of the ciliate spp. differed significantly from all other species tested with the exception of *Asterionella* sp. and the "large centric diatom" spp.

When examined by date, the sedimentation velocities of a number of species collected in the traps did vary by date at station 84. These included the "large centric diatom" spp., *Asterionella* sp., *Synedra* sp. and *Fragilaria* sp. (ANOVA, P=0.00, P=0.00, P=0.04 and P=0.01). At station 452, only one algal groups sedimentation velocity varied by date, the centric diatom sp. (ANOVA, P=0.01). There were no significant differences in the sedimentation velocities of the phytoplankton by sampling depth for either station.

There was no correlation (Pearson correlation, df = 156, r=0.04) between phytoplankton size measured in equivalent spherical diameter (ESD) and sedimentation velocity (Fig. 7). When the scatter plot was broken down into individual algal groups (Fig. 8), the group with the highest correlation between ESD and sedimentation velocity was the cyanobacteria, however this correlation was not significant (Pearson correlation, df = 7, r = 0.45).

Water temperature was plotted against algal sedimentation velocity calculated via the sediment traps (Fig. 9). The chrysophytes did appear to show a strong correlation with temperature, although it was not significant (Pearson correlation, df = 1, r= -0.98), while

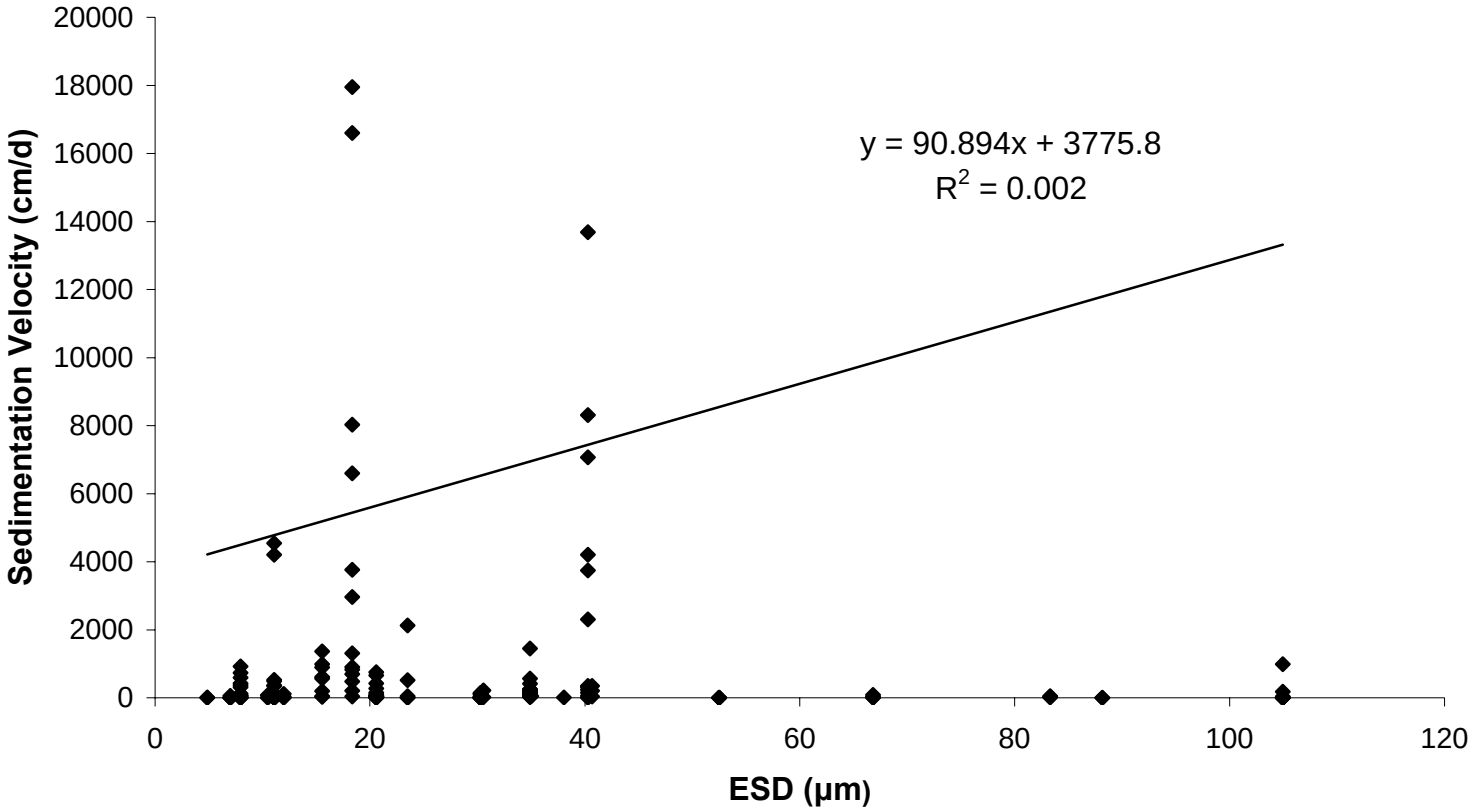


Figure 7 – Sedimentation velocity of the phytoplankton community in Lake Erie, April – October 2004 versus the average equivalent spherical diameter (ESD) of the algal cells. Sedimentation velocity was calculated with data obtained from sedimentation traps deployed in the central (station 84) and eastern (station 452) basins.

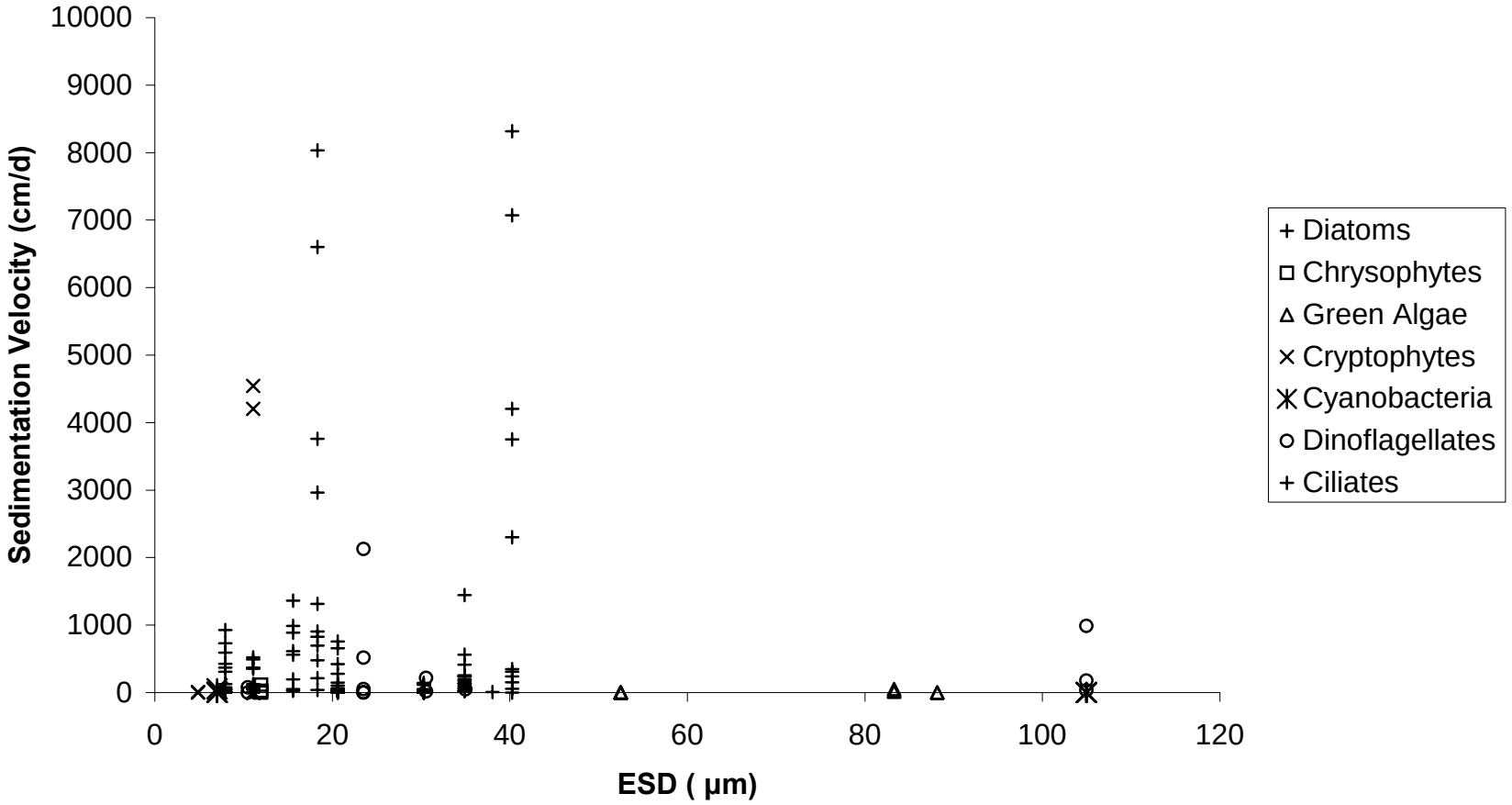


Figure 8 – Sedimentation velocity of the individual algal groups found in Lake Erie April – October 2004. Samples were collected from sediment traps deployed in both the central (station 84) and eastern (station 452) basins.

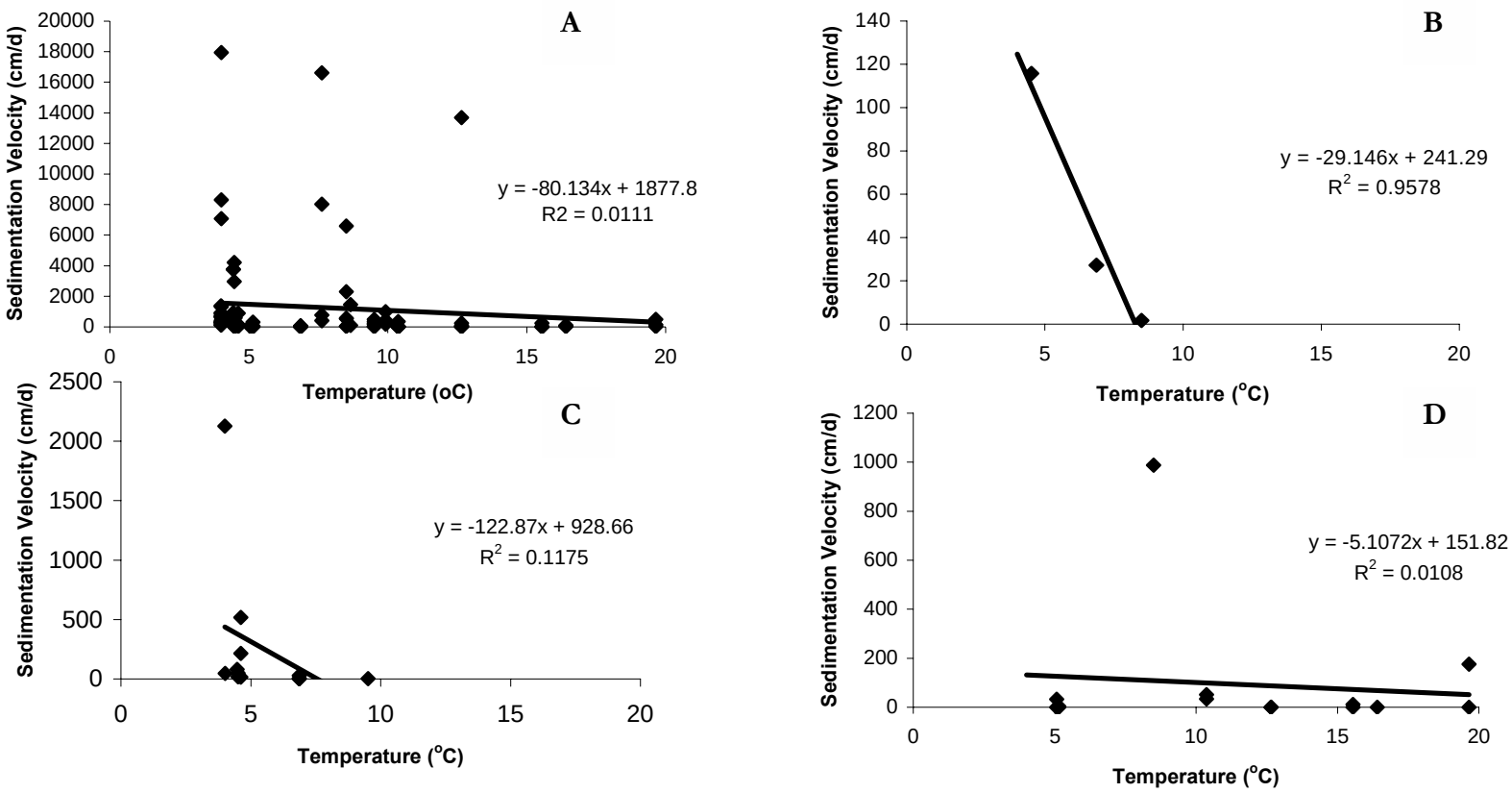


Figure 9 – Sedimentation of the individual algal groups that comprised the Lake Erie communities at stations 84 and station 452 (central and eastern basins respectively), from April – October 2004. Sediment traps were used to sample the sedimenting material in both basins. Algal groups include: diatoms (A), chrysophytes (B), dinoflagellates (C), green algae (D), ciliates (E), cyanobacteria (F) and cryptophytes (G)

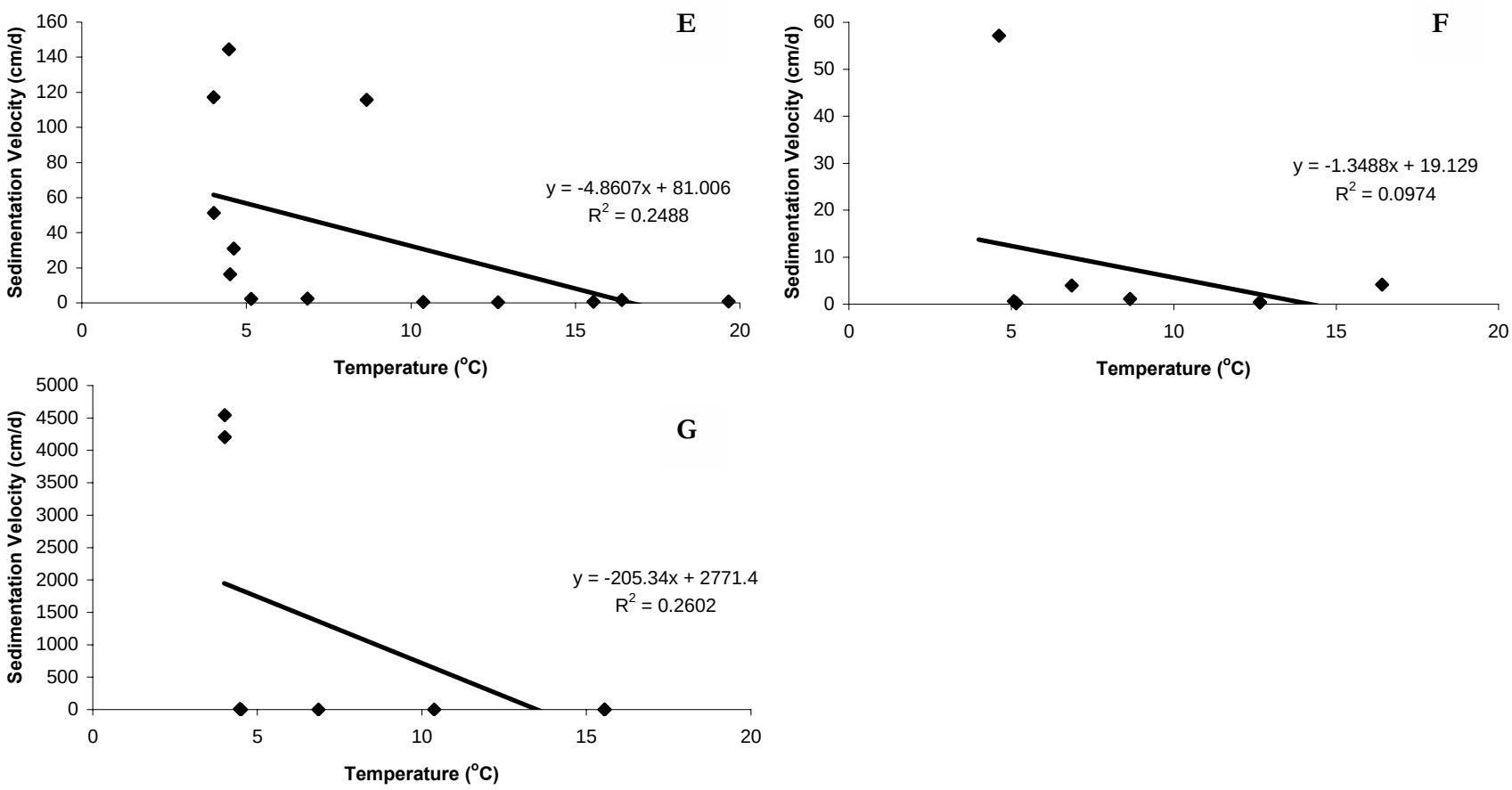


Figure 9 continued…

cryptomonad spp. and ciliate spp. showed modest correlations (Pearson correlation, df = 6 and 11, r = -0.51 and r = -0.50). All other algal groups had no correlation between their sedimentation velocity and water temperature at the time of sampling.

The sedimentation tower algal sedimentation velocity results were quite different than those calculated via the sedimentation traps (Table 4). As was the case for sedimentation rate, the towers were able to record negative sedimentation velocities. As well, some species were found in the towers that were not found in the sedimentation trap contents such as *Monoriphidium* sp. and *Chrysochromulina* sp. At station 84, the groups with the highest sedimentation velocities were *Ceratium hirundinella* at 306.897 cm/d, *Monoriphidium* sp. at 177.78 cm/d and *Synedra* sp. at 130.06 cm/d. At station 452, it was *Diatoma* sp. with the highest calculated sedimentation velocity of 297.01 cm/d, followed by *Dinobryon* sp. (266.75 cm/d) and *Asterionella* sp. (106.67 cm/d).

When the sedimentation velocities of the species calculated via the towers were compared to those calculated via the sedimentation traps (Fig. 10) a significant correlation was found (Pearson correlation, df = 9, r = 0.95).

Total Phosphorus (TP)

Epilimnetic TP at both stations varied between 10 and 26 μgP L^{-1} during stratification, without a consistent difference between stations (Table 5). The overall trend was for P to decline until early August then increase. Trend-lines were fitted to the TP curves from May to the end of the summer decline in TP

Table 4 – Phytoplankton sedimentation velocities calculated in the sedimentation towers for Lake Erie, April – October 2004. Stations 452 in the eastern basin and 84 in the central basin are included.

Station	Date	Depth (m)	*Plageoselmis nanoplanctica*	*Rhodomonas lens*	Centric Diatom sp.	Heteroflagellate spp.	Nanoflagellate spp.	*Dinobryon* sp.	Cryptomonad spp.
84	24-Jun-04	0-18	-55.668		188.910	-44.444	0.206	78.222	-136.998
84	21-Jul-04	0-16	-26.709		-58.093		-34.054	-16.026	-18.029
452	22-Jun-04	0-15			-79.699	-98.148	83.661	532.164	-136.398
452	20-Jul-04	0-10	8.681	2.003	-2.671	12.019	52.083	1.335	8.013
Average Station 84			**-41.189**		**65.408**	**-44.444**	**-16.924**	**31.098**	**-77.513**
Average Station 452			**8.681**	**2.003**	**-41.185**	**-43.064**	**67.872**	**266.750**	**-64.193**

Station	Date	Depth (m)	"Large" Cryptomonad spp.	*Chrysochromulina* sp.	Ciliate spp.	*Asterionella* sp.	*Synedra* sp.	*Fragilaria* sp.	*Ceratium hirundinella*	*Monoriphidium* sp.
84	24-Jun-04	0-18		-28.489	- 194.783	16.083	260.063		613.758	177.778
84	21-Jul-04	0-16	-0.133	-5.342	4.555	0.171	0.048	-0.389	0.037	
452	22-Jun-04	0-15		-70.389	58.431	210.969	58.447		-25.783	
452	20-Jul-04	0-10		-16.693	-26.214	2.362	0.059	-100.002	1.536	
Average Station 84			**-0.133**	**-16.915**	**-95.114**	**8.127**	**130.056**	**-0.389**	**306.897**	**177.778**
Average Station 452				**-43.541**	**16.108**	**106.665**	**29.253**	**-100.002**	**-12.124**	

Table 4 continued…

Station	Date	Depth (m)	Diatoma sp.	Giant Synedra sp.	*Anabaena* sp.	*Gymnodinium* sp.	"Large" *Gymnodinium* sp.	*Staurodesmus* sp.	Rotifer egg
84	24-Jun-04	0-18							
84	21-Jul-04	0-16			6.093	0.165		-7.970	0.011
452	22-Jun-04	0-15	297.013	133.320	141.270				
452	20-Jul-04	0-10			3.644	5.389	0.368		0.027
Average Station 84					**6.093**	**0.165**		**-7.970**	**0.011**
Average Station 452			**297.013**	**133.320**	**72.457**	**5.389**	**0.368**		**0.027**

Station	Date	Depth (m)	Green Algae spp.	*Peridinium* sp.	*Selenastrum* sp.	*Oocystis* sp.	Green Colonial spp.
84	24-Jun-04	0-18					
84	21-Jul-04	0-16	-12.687		-6.677	1.150	1.326
452	22-Jun-04	0-15					
452	20-Jul-04	0-10	134.882	0.117			
Average Station 84			**-12.687**		**-6.677**	**1.150**	**1.326**
Average Station 452			**134.882**	**0.117**			

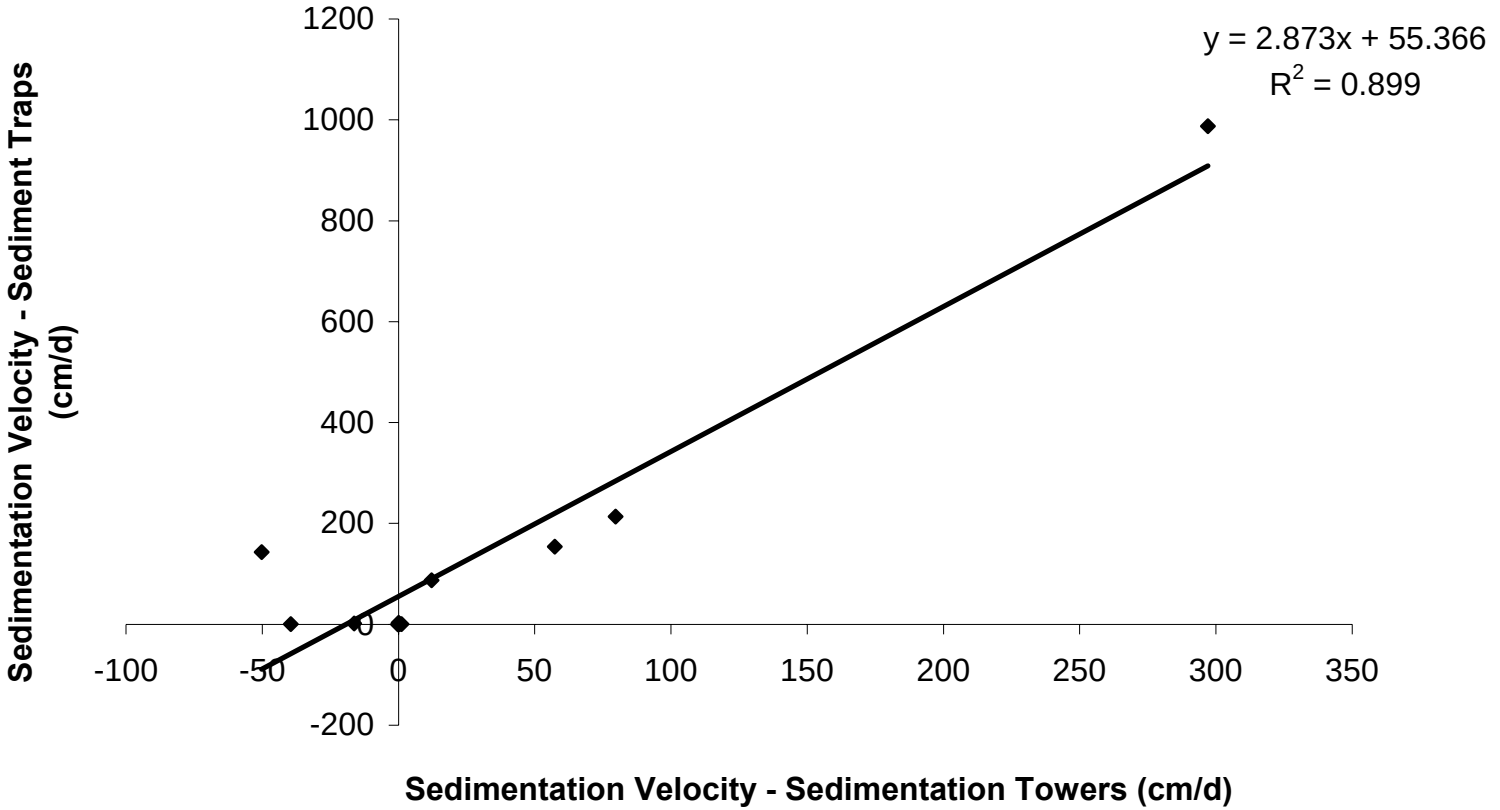


Figure 10 – Phytoplankton sedimentation velocity of the species present in the Lake Erie community calculated via the specially constructed in-laboratory sedimentation towers vs. calculated via *in situ* sediment traps. Data includes both the central basin (station 84) and the eastern basin (station 452) from April – October of 2004.

Table 5 – Total phosphorus concentrations in Lake Erie from May 26th – Oct 7th of 2004. Epilimnetic water was collected at station 84 in the central basin and station 452 in the eastern basin.

Date Sampled	Station	Depth (m)	Average TP (ug/L)	Areal TP (mg/m2)
27-May-04	84	0-13	17.703	230.134
2-Jun-04	84	0-13	21.524	279.807
24-Jun-04	84	0-18	13.312	239.610
21-Jul-04	84	0-16	14.174	226.791
4-Aug-04	84	0-15	11.699	175.486
26-Aug-04	84	0-17	20.116	341.974
22-Sep-04	84	0-20	15.056	301.122
6-Oct-04	84	0-18	17.686	318.343
26-May-04	452	0-9	12.572	113.149
2-Jun-04	452	0-9	16.568	149.109
22-Jun-04	452	0-15	16.824	252.367
20-Jul-04	452	0-10	14.236	142.361
5-Aug-04	452	0-11	15.083	165.918
26-Aug-04	452	0-11	10.780	118.581
20-Sep-04	452	0-26	9.966	259.107
7-Oct-04	452	0-20	26.482	529.640
Average Station 84			**16.409**	**264.158**
Average Station 452			**15.314**	**216.279**

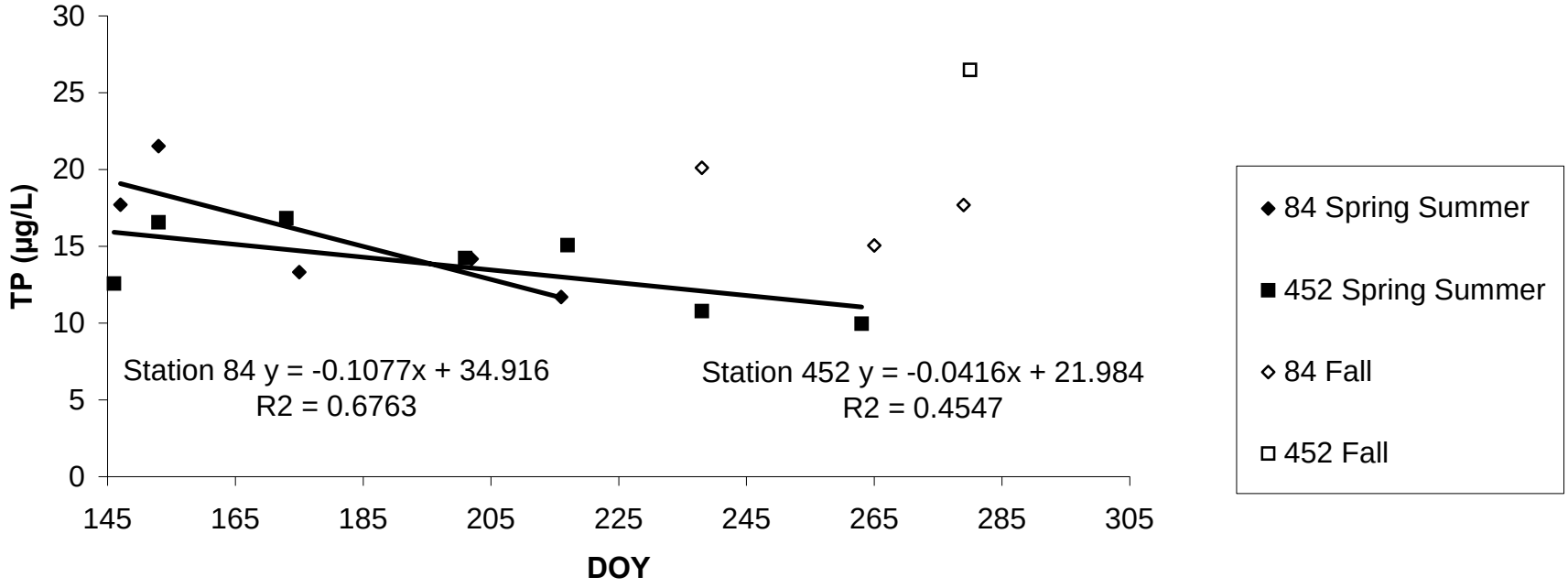


Figure 11 – Total phosphorus concentrations measured in the central and eastern basins of Lake Erie from May 26th to October 7th, 2004. Late summer points indicated by hollow symbols were not used in the calculation of rates of TP decline. DOY represents Day of the Year

(Fig. 11). These yielded estimate of the rate of decline in TP of 0.1077 and 0.0416 μg P L^{-1} d^{-1} for stations 84 and 452. If the average epilimnetic depth is multiplied by these rates during that period, this calculation yields an estimate of the decline of TP in areal units, for comparison to sedimentation.

Station 84 TP loss = – 0.1077 ugP$L^{-1}d^{-1}$ x 15.333 m

= –1.6514 mgP $m^{-2}d^{-1}$

Station 452 TP loss = -0.0416 ugP$L^{-1}d^{-1}$ x 13.875 m

= -0.5772 mgP $m^{-2}d^{-1}$

Nutrient Sedimentation

The sedimentation rates of each of the measured sediment components (P, C, N, Si and chlorophyll) were significantly different from one another (Table 6), as expected, with the exception of P and chlorophyll (paired t-test, P = 0.44). Carbon had the highest sedimentation rate with an average of 255.61 mg $m^{-2}d^{-1}$ at station 84 and 196.82 mg $m^{-2}d^{-1}$ at station 452. The lowest sedimentation rate was for P with an average rate of 1.64 and 1.37 mg $m^{-2}d^{-1}$ at stations 84 and 452. Only Si differed significantly between station 84 and 452 (t-test, P = 0.00). The sedimentation rate of all other sediment components did not differ significantly between the sampling stations.

At station 84, sedimentation rate of both P (ANOVA, P = 0.003) and chlorophyll (ANOVA, P = 0.003) differed significantly over the sampling period. The remaining sediment components did not. However, at station 452 all sedimentation rates showed significant differences by date. Calcium concentrations measured in the sedimentation traps did show an increase at all trap depths at station 452 in October, therefore calcite precipitation may have occurred.

Table 6 – Nutrient sedimentation rates (mg/m^{2}d) measured in Lake Erie's central basin at station 84 and eastern basin at station 452. Samples were collected via sedimentation traps deployed from April – October of 2004.

Station	Date Sampled	Depth (m)	P	C	N	Si	Chlorophyll
84	13-April - 2-Jun	18	2.351	239.178	25.811	23.320	8.746
84	13-April - 2-Jun	21	2.483	255.581	28.849	24.882	9.692
84	2-Jun - 21-Jul	18	0.668	214.206	21.225	20.138	1.119
84	2-Jun - 21-Jul	21	0.945	221.160	21.345	23.018	1.402
84	21-Jul - 26-Aug	18	0.452	407.947	39.624	14.136	0.124
84	21-Jul - 26-Aug	21	0.793	275.947	23.194	18.745	0.329
84	26-Aug - 6-Oct	18	2.419	232.038	24.311	24.470	0.939
84	26-Aug - 6-Oct	21	2.996	198.856	21.495	34.853	0.889
452	13-April - 2-Jun	20	2.161	322.278	42.748	18.345	3.446
452	13-April - 2-Jun	30	3.122	334.333	34.591	14.678	3.697
452	13-April - 2-Jun	40	2.010	266.057	32.750	18.207	3.382
452	13-April - 2-Jun	50.7	2.038	255.023	29.590	19.919	2.068
452	2-Jun - 5-Aug	20	0.530	167.109	15.796	9.653	0.254
452	2-Jun - 5-Aug	30	0.556	158.750	13.515	9.963	0.182
452	2-Jun - 5-Aug	40	0.335	179.170	15.992	8.242	0.177
452	2-Jun - 5-Aug	50	0.291	174.528	15.581	8.101	0.179
452	5-Aug - 7-Oct	20	1.788	115.971	6.788	10.052	0.433
452	5-Aug - 7-Oct	30	1.742	113.051	6.403	14.675	0.334
452	5-Aug - 7-Oct	40	1.076	134.196	8.965	11.459	0.247
452	5-Aug - 7-Oct	50.7	0.775	141.372	8.772	13.176	0.147
Average Station 84			**1.639**	**255.614**	**25.732**	**22.945**	**2.905**
Average Station 452			**1.369**	**196.820**	**19.291**	**13.039**	**1.212**

Table 7 – Calcium concentrations in sediment trap contents for Lake Erie central (station 84) and eastern (station 452) basins April – October 2004

Date	Station	Depth (m)	Ca (mg/L)
2-Jun-04	84	18	1.817
21-Jul-04	84	18	1.050
26-Aug-04	84	18	1.655
6-Oct-04	84	18	1.383
2-Jun-04	84	21	2.190
21-Jul-04	84	21	1.305
26-Aug-04	84	21	1.227
6-Oct-04	84	21	1.402
2-Jun-04	452	20	1.129
5-Aug-04	452	20	1.705
7-Oct-04	452	20	7.948
2-Jun-04	452	30	1.595
5-Aug-04	452	30	2.170
7-Oct-04	452	30	9.837
2-Jun-04	452	40	1.483
5-Aug-04	452	40	2.209
7-Oct-04	452	40	9.290
2-Jun-04	452	50.7	1.332
5-Aug-04	452	50	2.160
7-Oct-04	452	50.7	7.161

during this period (Table 7). There were no significant differences in sedimentation rate among depths for any of the sediment components sampled. The sedimentation rates for C and N were strongly correlated (Fig. 12), while the other sediment components were less strongly related. P was most strongly related to Si, and only weakly related to C.

The sedimentation rate estimates using towers in the laboratory were highly variable (Table 8). One difference that was apparent between the tower measurements and the sediment trap measurements was that the towers measured net sedimentation, therefore could record negative sedimentation rates, while the sediment traps measured downflux only, which cannot be negative. In fact, the tower measurements for all sediment components were lower than those recorded for the lake (Fig 13). There were no significant correlations found between the tower measurements and the lake measurements.

Unlike the case for sedimentation rate, the sedimentation velocity of both C and N varied significantly between the two sampling stations (C: t-test, $P = 0.00$, N: t-test, $P = 0.02$) (Table 9). As well, all sedimentation velocity components differed significantly from one another with the exception of P and Si (paired t-test, $P = 0.32$), C and chlorophyll (paired t-test, $P = 0.29$) and N and chlorophyll (paired t-test, $P = 0.07$).

As was the case for the sedimentation rate of P and chlorophyll, the sedimentation velocities of these two components differed significantly by sampling date at station 84 (P: ANOVA, $P = 0.00$, chlorophyll: ANOVA, $P = 0.00$) (Table 9). However, unlike the sedimentation rate statistics, at station 452 the C and Si sedimentation velocities did not differ significantly by date, while the

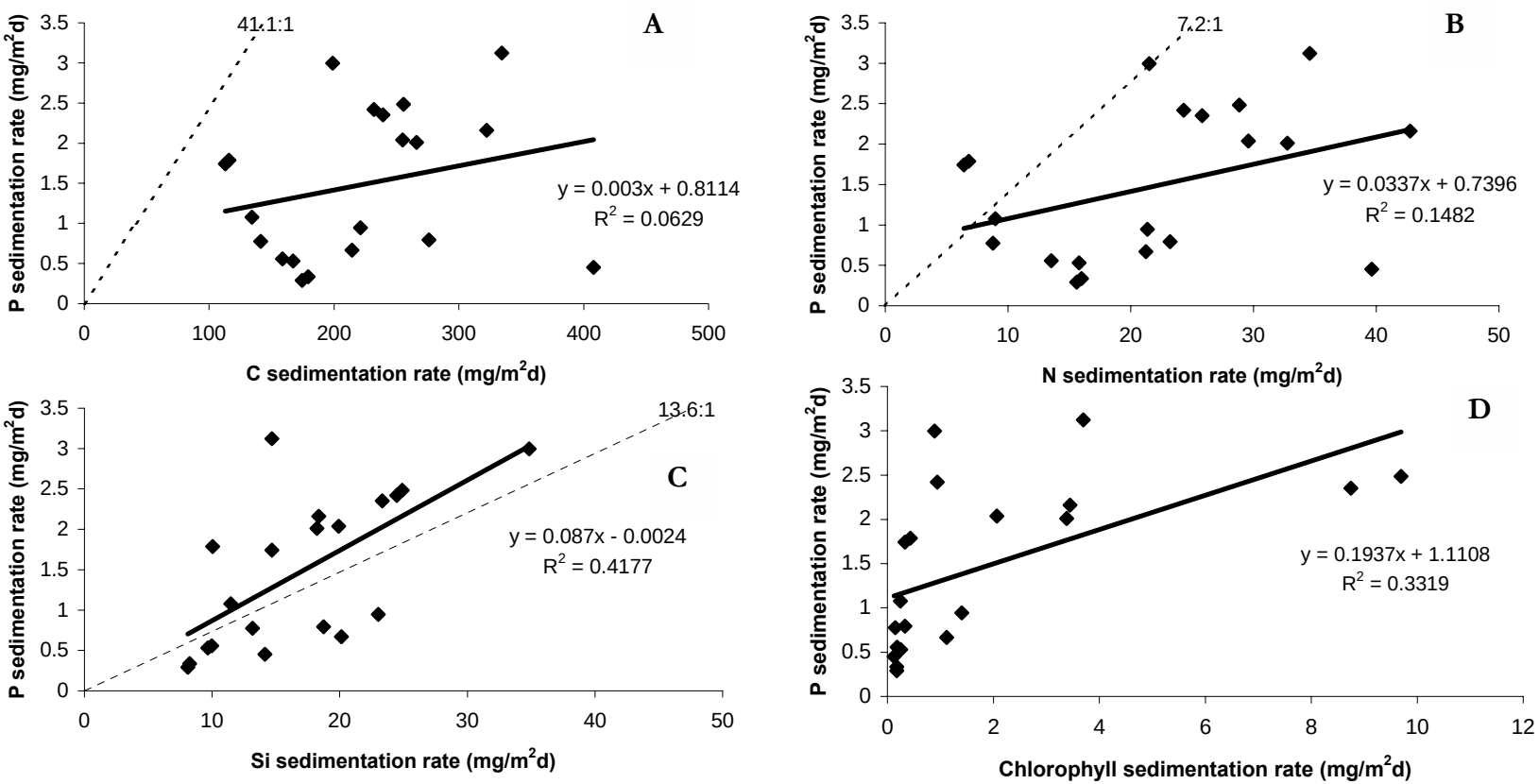


Figure 12 – Comparisons of sedimentation rates for different sediment components as measured with sedimentation traps deployed in Lake Erie from April to October 2004. Graphs include measurements from both the central basin at station 84 and the eastern basin at station 452. The dashed line for graphs A, B C, E, G and H represent the Redfield ratios (Wetzel, 2001) while the solid lines indicate the linear regressions provided on the graphs.

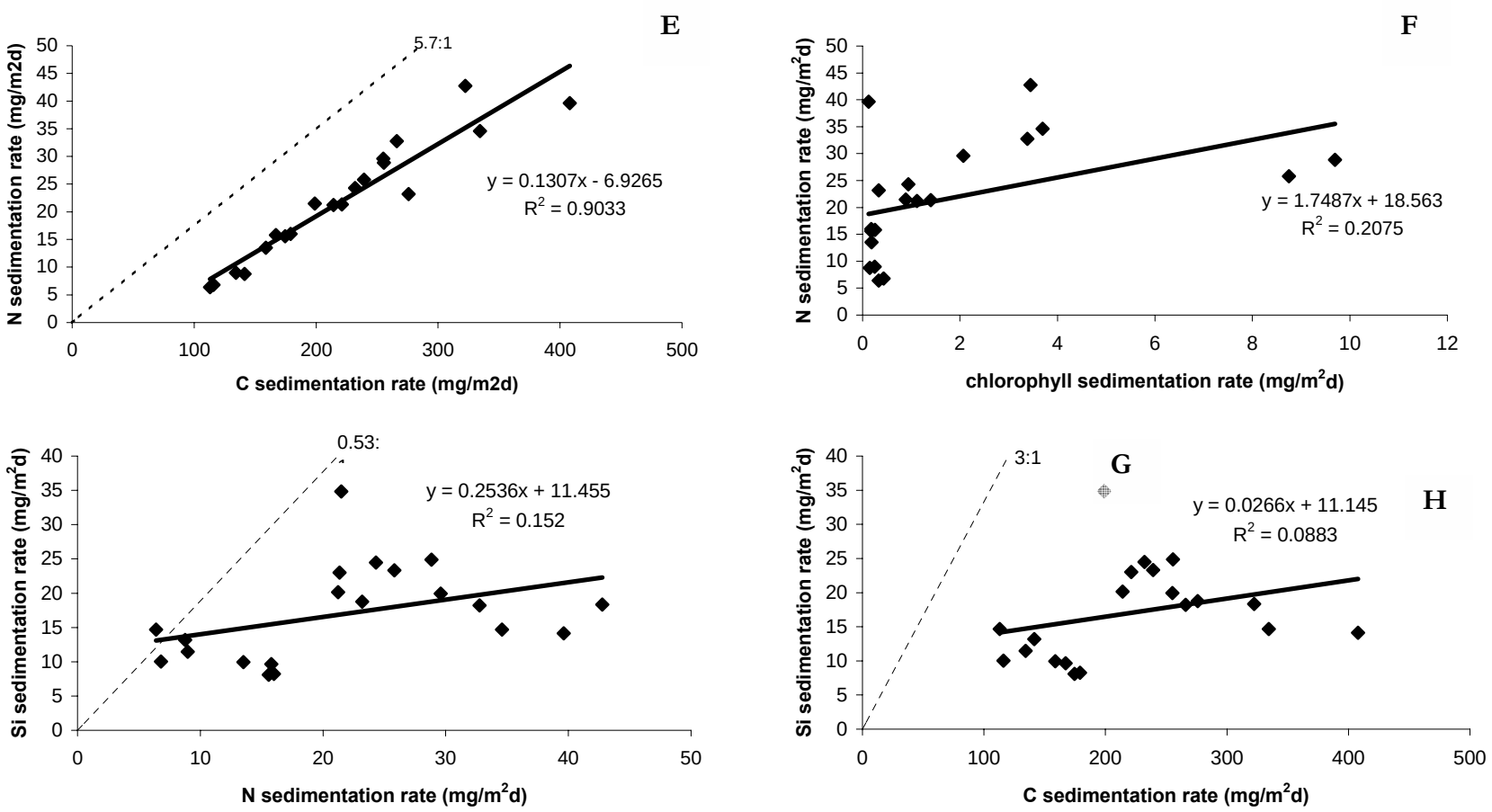
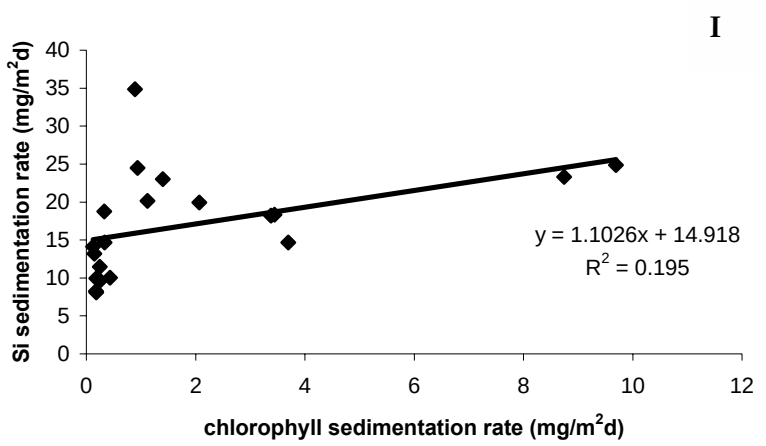


Figure 12 continued…



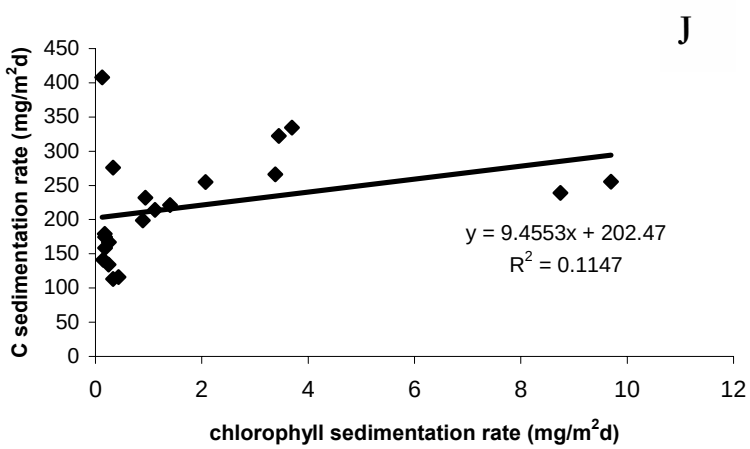


Figure 12 continued…

Table 8 - Nutrient sedimentation rates (mg/m^{2}d) for Lake Erie calculated via in laboratory sedimentation towers. Data includes station 84 in the central basin and station 452 in the eastern basin, from April – October 2004.

Station	Date Collected	Depth (m)	P	C	N	Si	Chlorophyll
84	24-Jun-04	0-18	-2.820	309.333	33.778	5.927	0.011
84	21-Jul-04	0-16	0.220	-1232.000	-122.667	-1.052	-0.219
84	26-Aug-04	0-17	0.000	611.556	-618.667	3.254	-0.219
84	6-Oct-04	0-18	0.045	48.000	12.444	-1.824	-0.051
452	22-Jun-04	0-15	6.610	264.889	12.444	1.840	-0.006
452	20-Jul-04	0-10	11.030			0.577	-0.040
452	26-Aug-04	0-17	0.017	-341.333	-14.222	1.052	0.195
452	7-Oct-04	0-20	-0.378	133.333	21.333	-0.662	-0.143
Average Station 84			**-0.639**	**-65.778**	**-173.778**	**1.576**	**-0.120**
Average Station 452			**4.320**	**18.963**	**6.519**	**2.000**	**0.001**

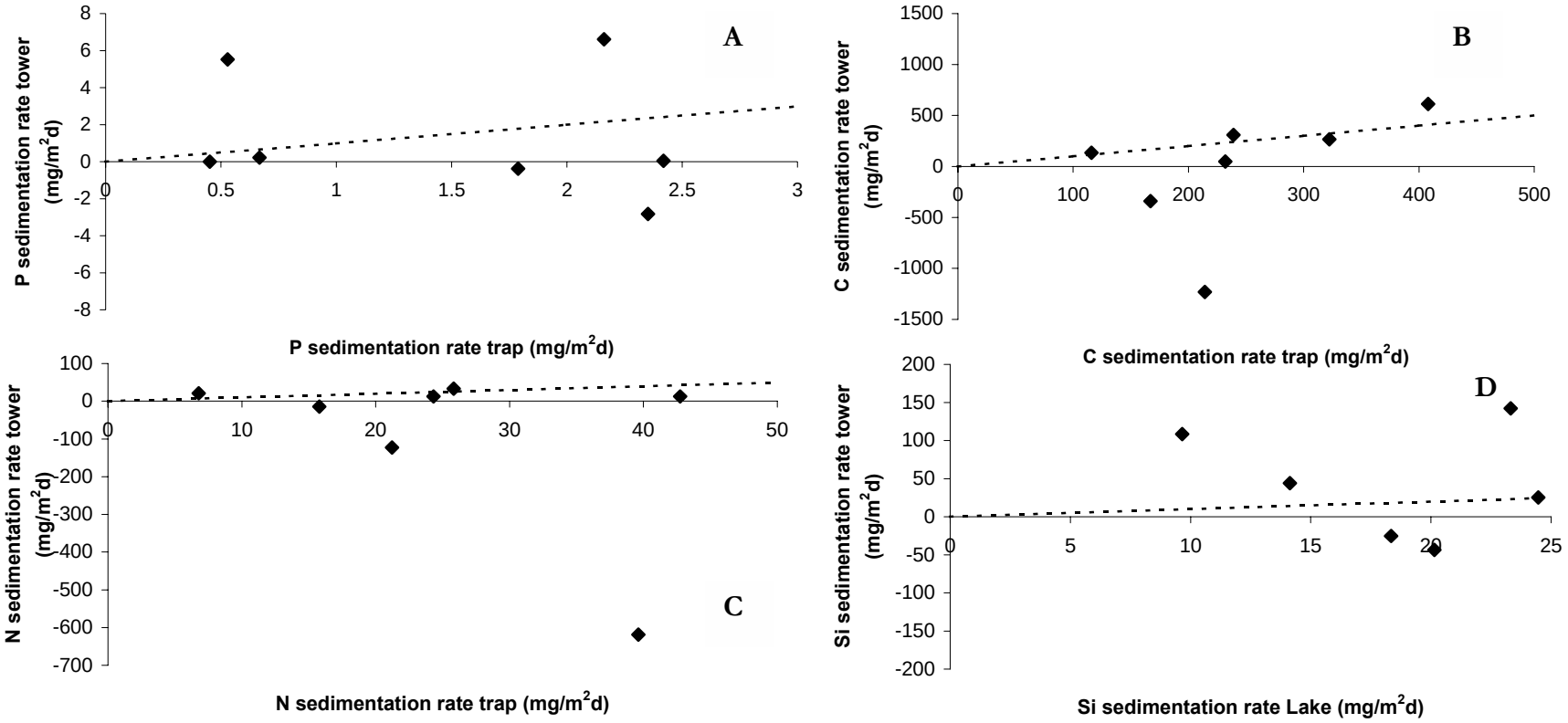


Figure 13 – Sedimentation rates of the sediment components measured in the laboratory sedimentation towers compared to sedimentation rates measured by sedimentation traps in Lake Erie's central (station 84) and eastern basins (station 452). Data was collected from April to October 2004. The dashed lines represent the 1:1 line.

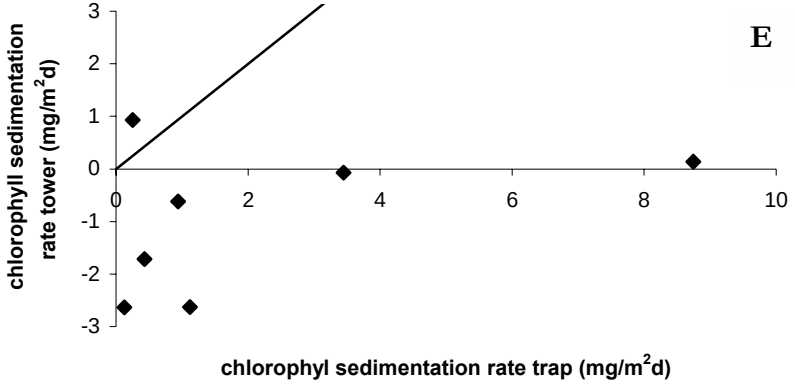


Figure 13 continued…

Table 9 - Nutrient sedimentation velocities (cm/d) in Lake Erie at station 84 in the central basin and station 452 in the eastern basin, April – October 2004. Sedimenting material was collected *in situ* with sedimentation traps.

Station	Date Sampled	Depth (m)	P	C	N	Si	Chlorophyll
84	13-April - 2-Jun	18	20.112	90.256	59.564	43.032	1742.221
84	2-Jun - 21-Jul	18	11.114	87.610	39.306	16.111	107.127
84	21-Jul - 26-Aug	18	7.737	128.151	74.762	60.530	10.872
84	26-Aug - 6-Oct	18	41.760	64.500	30.200	34.917	0.075
84	13-April - 2-Jun	21	24.956	108.221	73.657	46.586	789.491
84	2-Jun - 21-Jul	21	12.321	81.970	53.692	61.175	105.056
84	21-Jul - 26-Aug	21	10.296	97.796	45.037	19.615	30.531
84	26-Aug - 6-Oct	21	50.782	77.906	46.729	44.960	0.073
452	13-April - 2-Jun	20	36.872	205.491	197.301	32.880	635.932
452	2-Jun - 5-Aug	20	7.175	64.308	32.909	13.183	24.962
452	5-Aug - 7-Oct	20	21.011	65.626	20.932	10.868	49.771
452	13-April - 2-Jun	30	69.417	389.514	329.440	60.073	905.312
452	2-Jun - 5-Aug	30	18.048	197.031	76.293	24.003	26.626
452	5-Aug - 7-Oct	30	65.530	184.037	57.460	27.524	85.817
452	13-April - 2-Jun	40	39.805	390.303	377.886	85.626	789.820
452	2-Jun - 5-Aug	40	11.341	365.654	254.424	57.917	129.447
452	5-Aug - 7-Oct	40	127.527	267.628	88.383	46.601	81.500
452	13-April - 2-Jun	50.7	39.966	452.704	455.228	58.385	553.339
452	2-Jun - 5-Aug	50	16.714	503.445	322.359	63.431	219.437
452	5-Aug - 7-Oct	50.7	39.774	417.554	95.943	15.524	143.314
	Average Station 84		**22.385**	**92.051**	**52.868**	**40.866**	**348.181**
	Average Station 452		**41.098**	**291.941**	**192.380**	**41.335**	**303.773**

remaining three elements sampled did (P:, ANOVA, P = 0.01, N: ANOVA, P = 0.02 and chlorophyll: ANOVA, P = 0.00). With respects to sedimentation velocity by depth, as with sedimentation rate, there was no significant difference measured with the exception of C at station 452 (ANOVA, P = 0.01).

In the case of both stations, carbon and chlorophyll had high sedimentation velocities while P had the lowest (Fig. 14). Station 452 had the highest sedimentation velocities with the exception of chlorophyll. As was the case for sedimentation rate, C and N seem to have the strongest relationship (Fig. 15) followed by Si and N.

For the sedimentation tower data, with the exception of Si, the sedimentation velocities of the sediment components were highest at station 452 (Table 10). For station 84 the highest sedimentation velocity was Si (63.14 cm/d) while the lowest was N (-195.78 cm/d). Conversely, at station 452 the highest sedimentation velocity recorded was for C (143.65 cm/d) and the lowest was for Si (-71.49 cm/d). As was the case for the sedimentation rates of the of the sediment components, no significant correlation was found between the sedimentation velocities calculated by the trap method with those calculated by the tower method (Fig. 16).

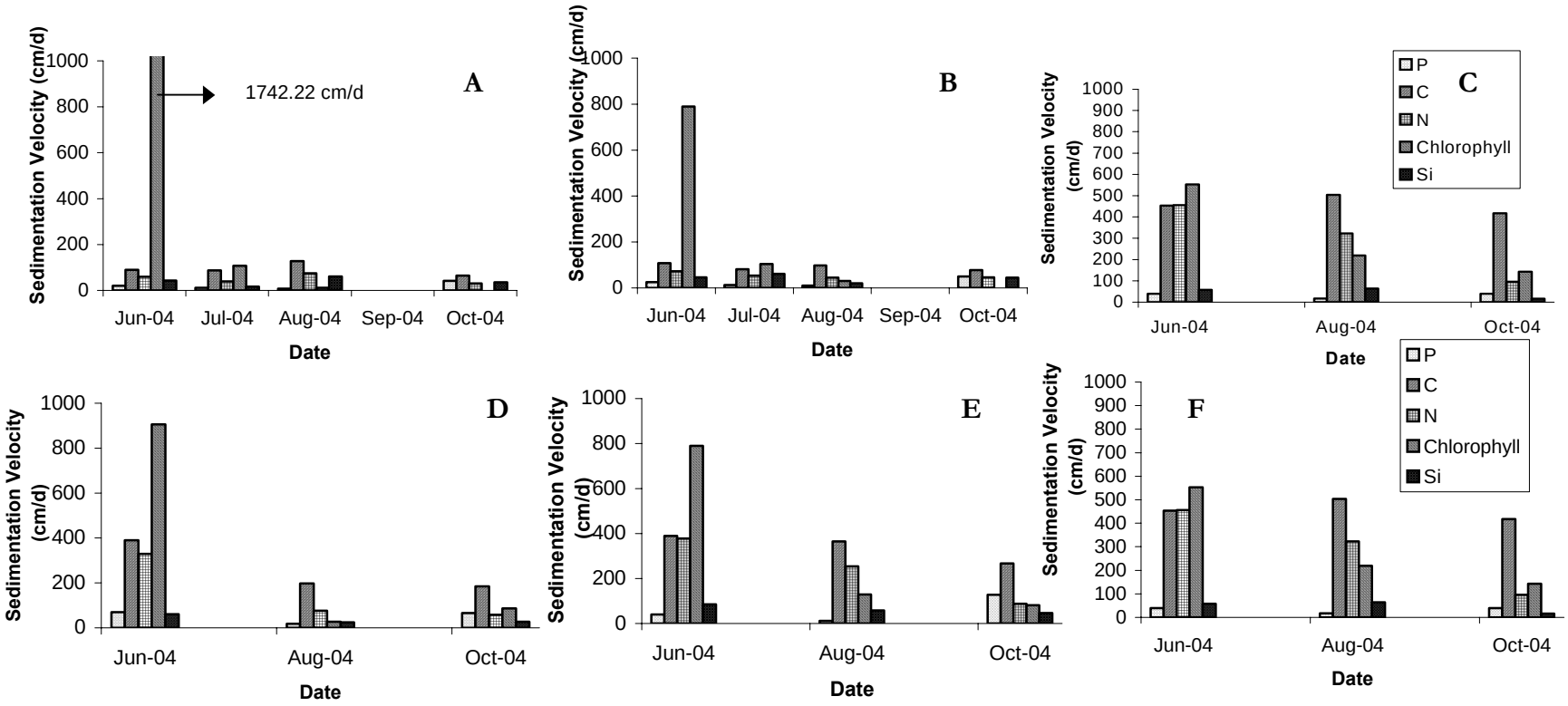


Figure 14 – Nutrient sedimentation velocities calculated by the sediment trap method for the sediment components at each sampling depth for stations 452 and 84 in Lake Erie, 2004. Station 84: 18 m (A) 21 m (B) Station 452: 20 m (C) 30 m (D) 40 m (E) 50.7 m (F)

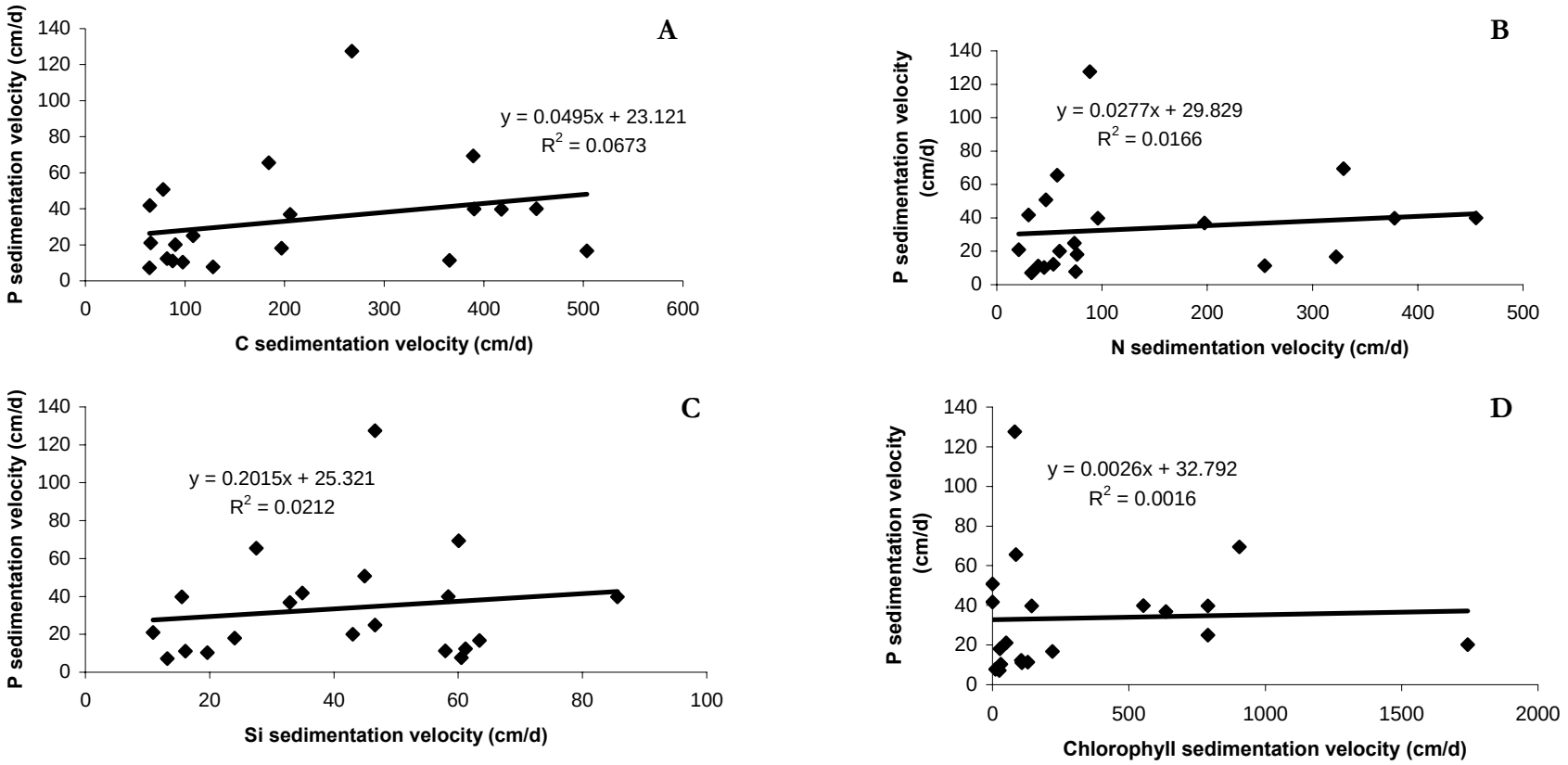
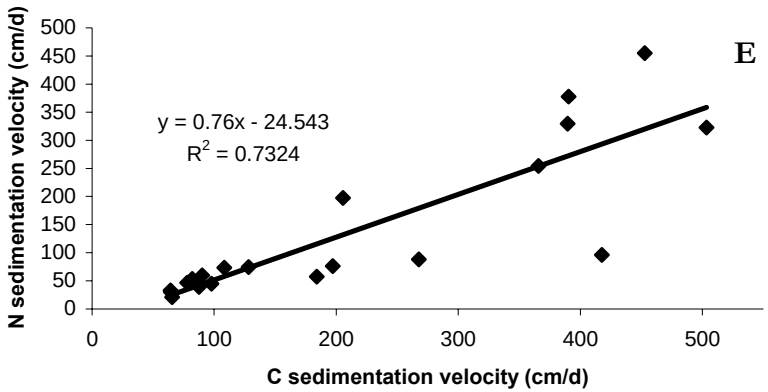
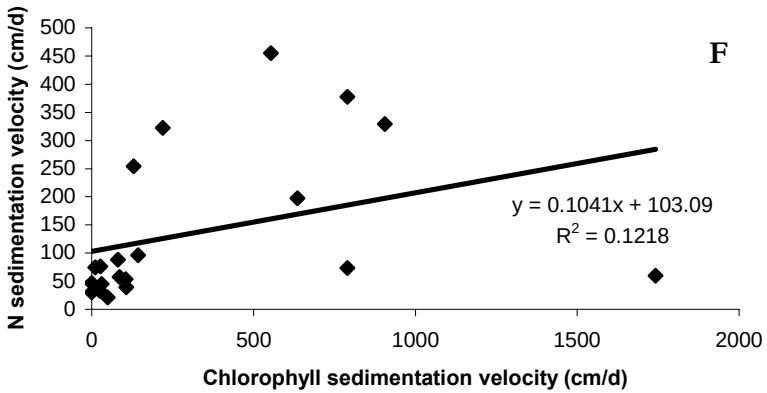
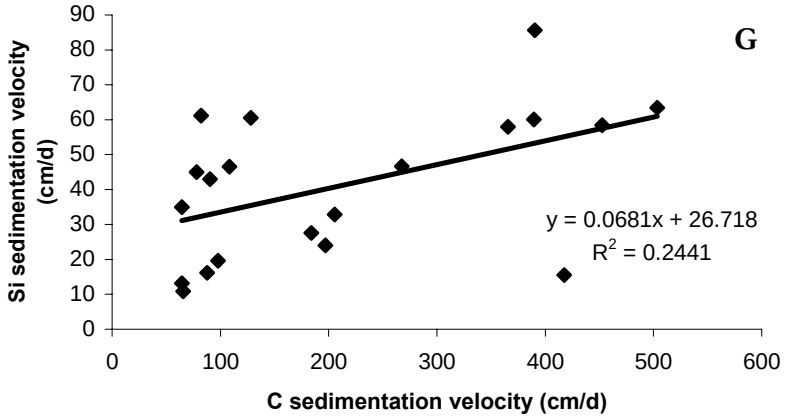


Figure 15 - Comparison of the sedimentation velocities calculated in both the central (84) and eastern basins (452) for the different sediment components measured via the sedimentation traps. The traps were deployed in Lake Erie from April – October 2004.







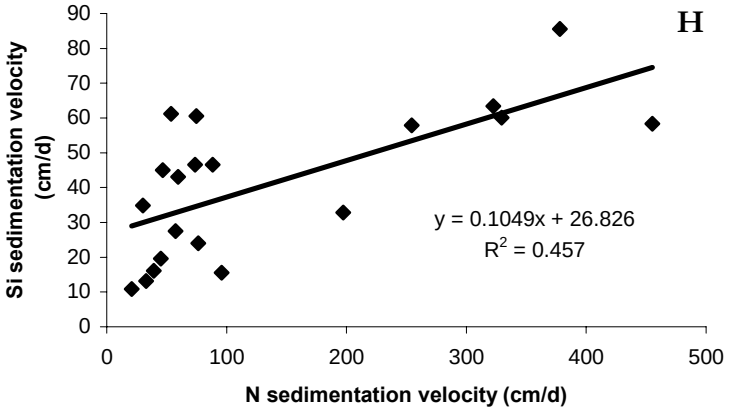
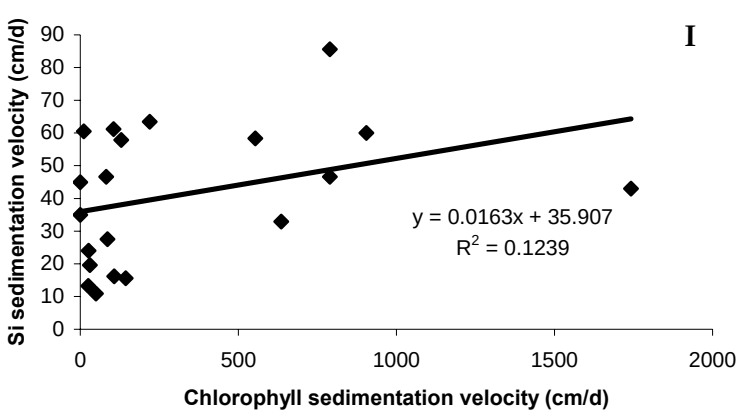


Figure15 continued…



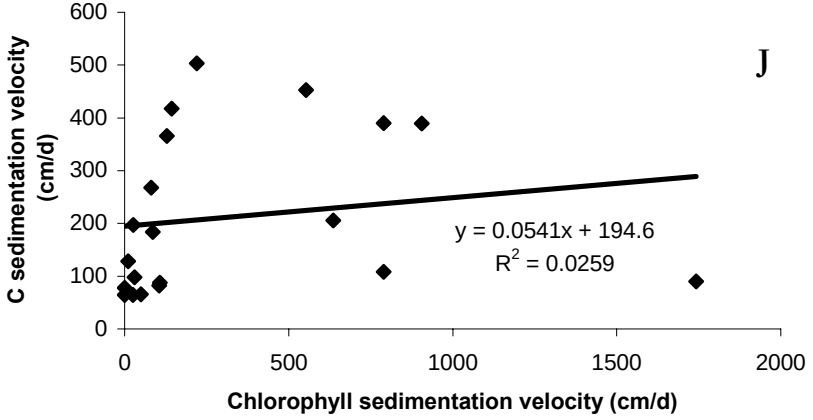


Figure 15 continued…

Table 10 - Nutrient sedimentation velocities (cm/d) for Lake Erie, station 84 and 452, 2004, calculated in specially constructed sedimentation towers. The incubation period for the experiment was one hour.

Station	Date Collected	Depth (m)	P	C	N	Si	Chlorophyll
84	24-Jun-04	0-18	-33.516	329.617	261.564	247.443	16.339
84	21-Jul-04	0-16	2.034	-835.254	-908.642	-70.778	-3.645
84	26-Aug-04	0-17	3.574	193.759	-173.468	52.469	-151.104
84	6-Oct-04	0-18	16.264	20.303	37.417	23.415	-6.975
452	22-Jun-04	0-15	75.663	238.597	154.248	-124.080	-21.051
452	20-Jul-04	0-10	102.188			-219.715	-197.633
452	26-Aug-04	0-17	5.273	113.239	21.437	65.892	76.268
452	7-Oct-04	0-20	-4.643	79.105	65.467	-8.058	-24.894
Average Station 84			**-2.911**	**-72.894**	**-195.782**	**63.137**	**-36.346**
Average Station 452			**44.620**	**143.647**	**80.384**	**-71.490**	**-41.827**

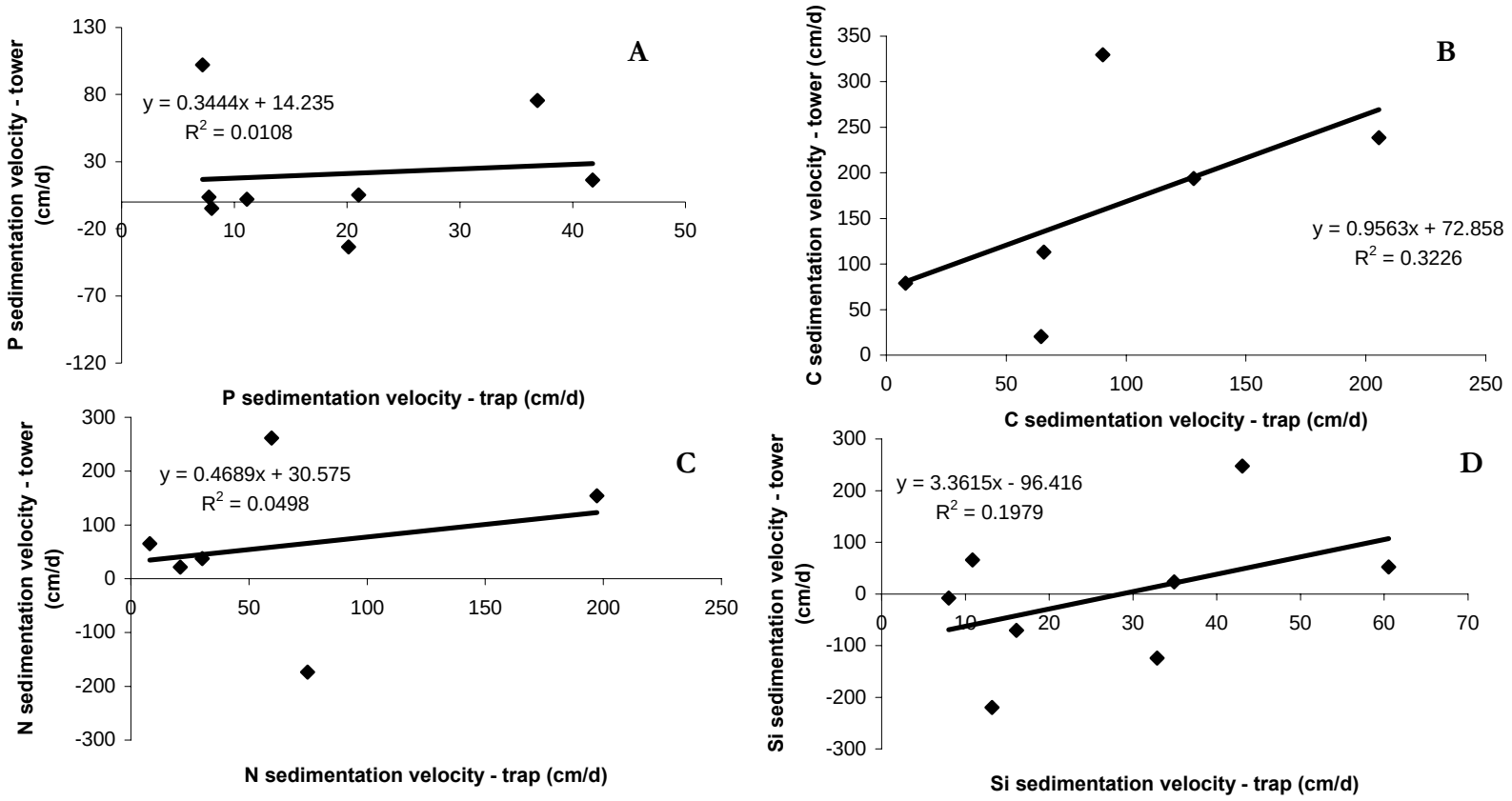


Figure 16 – Lake Erie sedimentation velocities for the sediment components at station 84 (central basin) and 452 (eastern basin), April – October 2004, calculated by traditional sediment traps vs. calculated by in-laboratory sedimentation towers.

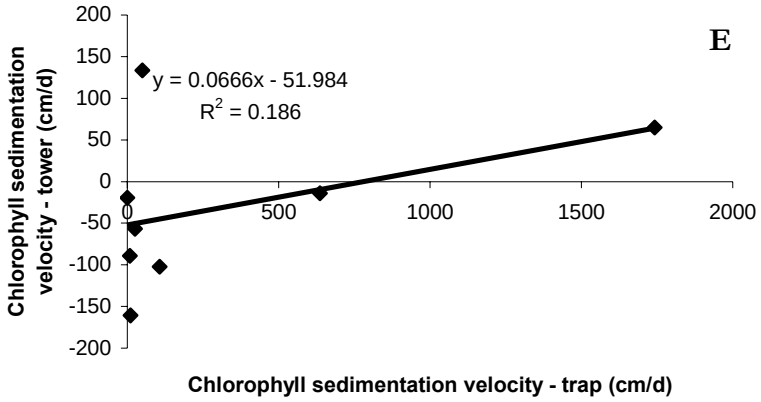


Figure 16 continued…

Discussion

Phytoplankton Sedimentation

Since the introduction of the zebra mussel to Lake Erie, the phytoplankton community composition has been reported to be largely diatom-dominated with maximums in spring and fall (Guildford *et al.,* 2005; Barbiero *et al.,* 2006; Ghadouani and Smith, 2005). In 2004, most of the species found in the sediment trap material were diatoms (Table 1). This is consistent with other sediment trap studies where diatoms often contribute the most to total phytoplankton flux , e.g. Horn and Horn (1993).

Many of these diatom species had the highest average sedimentation velocities of the community, probably due to their high-density siliceous frustules (Table 3). *Aulacoseira* sp.*,* "other colonial centric diatom spp." as well as the "large non-colonial centric diatom spp. ", were the fastest sinking algae at both stations. It was my original hypothesis that the diatoms would be the taxa with the highest sedimentation velocities thus they would contribute the most to P sedimentation. This is consistent with Poister and Armstrong (2003) who concluded that in Trout Lake, Wisconsin, the sedimentation rate of P was directly linked to diatom sedimentation. This was determined using biogenic silica concentrations as an indicator of diatom abundance. In Lake Erie, P sedimentation rate was most strongly related to Si sedimentation rate (Fig. 8), further supporting a relationship between diatoms and P sedimentation.

Not only will the presence of diatoms in the community affect the sedimentation of P, but also the specific taxa present may influence P sedimentation dynamics. The colonial diatoms *Fragilaria* sp. and *Asterionella* sp. are

often the fastest sinking algae in sedimentation studies. For example in Lake St. George, Ontario, *Asterionella formosa* was the fastest sinking algae at 40 ± 28 cm/d while *Fragilaria crotonensis* sank at a rate of 27 ± 13 cm/d (Burns and Rosa, 1980). In the Reservoir Saidenbach *Fragilaria crotonensis and Asterionella formosa* were again the fastest at 320-430 cm/d and 260-300 cm/d respectively (Horn and Horn, 1993). Finally in Lake Constance *Fragilaria sp.* sank at a rate of 140 cm/d while *Asterionella* sp. sank at a rate of 120 cm/d (Sommer, 1984 as referenced by Huisman and Sommeijer, 2002). These velocities are consistent with those recorded for Lake Erie for these species (Table 3). In the Lake Erie phytoplankton community, however, one of the seven taxa examined, *Aulacoseira* sp., had higher average sedimentation velocities, significantly different from most other species (Table 3). Since *Aulacoseira* sp. is a colonial centric species that can form large chains, it may sink faster than the non-colonial centric diatoms tested, thus increasing the sedimentation velocity of P accordingly. Ciliophora, which I counted along with the phytoplankton, sank more slowly than other groups (Table 3). The ciliates have cilia and are strongly motile, which probably accounts for their slower sedimentation velocity. Although I was unable to demonstrate significant differences among other taxa, this is most likely a matter of statistical power. Each species, with its distinct shape, size, density and motility, likely sinks at a different rate. There may even be differences within species depending on intrinsic and extrinsic factors.

Of the seven algal species tested, three diatoms showed significant differences in their sedimentation rates between the central and eastern basins, *Asterionella* sp., *Fragilaria* sp. and "large centric non-colonial diatom spp. " (Table

1). However, there were no differences in sedimentation velocity of these species between the sampling basins. Thus the differences in sedimentation rate were likely caused by differences in abundance (Horn and Horn, 1993) which can be affected by a number of factors such as light intensity and grazing pressure (Burns and Rosa, 1980; Muzumder *et al.*, 1992). Klerks *et al.* (1996) noted that in the western basin of Lake Erie, the presence of zebra mussels has decreased seston levels and increased bulk sedimentation through filtering and feces production, thereby increasing light intensity and light penetration. The same may hold true in the central and eastern basins, but to varying degrees since the central and eastern basins vary in maximum depth, with the central basin having a maximum of 21 m and the eastern having a maximum of 60 m. Due to its shallowness, the central basin may also experience greater resuspension and that alone could affect the sediment trapping of diatoms (Reynolds, 1984).

As particles sink, natural collisions result in the aggregation of material. According to Stoke's Law, as particle size increases, so should the sedimentation velocity (Hutchinson, 1967). In Lake Erie, neither the sedimentation rate nor sedimentation velocity of the most abundant species in the community showed any significant change with depth (Table 1 and 3). Droppo *et al.* (1997) explained that despite an increase in size, the density of aggregated material often decreases due to an increase in porosity. Bound water, contained within the pores, brings the density of the aggregate closer to the density of water, slowing its settling speed (Droppo, 2001).

In Lake Erie, no relationship was found between the sizes of the major phytoplankton groups, measured as equivalent spherical diameter, and

sedimentation velocity (Figure 3 and 4). These results are consistent with Hudson and Taylor (2005), Poister (1995) and Poister and DeGuelle (2005) who also found no relationship between particle size (measured as mean algal diameter) and sedimentation velocity. Along with an increase in porosity with aggregation, mechanisms employed by the algal cells to stay in the mixed layer can have a greater affect on sedimentation velocity than particle size. Some studies that have found a relationship between particle size and sedimentation velocity such as Mazumder *et al.* (1989) and Larocque *et al.* (1996) are enclosure studies which may not be truly reflective of in lake conditions (Hudson and Taylor, 2005). For example, enclosure studies measure mostly primary sedimentation and omit secondary sedimentation (resuspended sediment from the lake bottom) via their design, and in a lake system, secondary sedimentation plays an important role in sedimentation dynamics (Hudson and Taylor, 2005).

Over the sampling period, the sedimentation rates of the various species changed significantly (Table 1), reflecting shifts in the community composition in response to thermal stratification. In the spring, *Aulacoseira* sp., "non-colonial centric diatom spp. ", "colonial centric diatom spp. " and *Asterionella* sp. were the cells found most in the sediment trap material (Table 1). In the summer during the stratified period, *Synedra* sp. and *Fragilaria* sp. dominated the trap material. At fall mixing, those diatoms that were most abundant in the spring increased in abundance once again, along with *Fragilaria* sp. The greater abundance of diatoms during the spring and fall mixed seasons is consistent with Visser *et al.* (1996) who found that the number of non-buoyant algae per m^2 was higher in an artificially mixed lake than in a stratified lake. The community shift from the colonial and

non-colonial centrics to *Synedra* sp. and *Fragilaria* sp. may be due to the fact that *Synedra* sp. and *Fragilaria* sp. have a greater form resistance since they are long and thin and, in the case of *Fragilaria* sp., can form long thin chains. By increasing form resistance, sedimentation velocity is reduced, which would be advantageous in the smaller mixed layer present during stratification (Hudson and Taylor, 2005). The rapid decline in species diversity from the spring to summer may be a result of a draw down in dissolved Si upon stratification as noted by Guildford *et al.* (2005) in Lake Erie in 1997. When Si is limiting, diatoms become Si deficient, which may decrease their abundances and therefore their sedimentation rates (Waite *et al.,* 1997).

At station 84, the sedimentation velocities of the "large non-colonial centric diatom spp. " and *Asterionella* sp. varied significantly over the sampling period with an apparent decrease from spring to summer and an increase in the fall (Table 3). The sedimentation velocities of *Synedra* sp. and *Fragilaria* sp. also varied significantly over the sampling period, however no pattern throughout the seasons could be observed. At station 452, the "non-colonial centric diatom spp. " varied significantly over the sampling period at all of the trap depths with the exception of 40 m. Again, there was a decrease in sedimentation velocity from the spring to summer with an increase occurring in the fall (Table 3). These taxa that showed significant change in their sedimentation velocities at both stations may be changing their colony size, degree of silicification, lipid content or vacuole production, to stay in the smaller mixed layer brought on by stratification (Fig.1).

My results are also contrary to the principle that as the water temperature increases from the spring to the summer, it becomes less viscous and the

sedimentation velocity of the phytoplankton should increase (Hutchinson, 1967). In fact, no correlation was found between temperature and sedimentation velocity (Fig. 5) and in many instances the sedimentation velocity decreased from spring to summer. In Lake Erie, many of the species making up the phytoplankton community use various methods to regulate their position in the water column with respects to light intensity, such as flagella and gas vacuoles (Burns and Rosa, 1980; Thomas and Walsby, 1985). These results further reinforce that biological adaptations employed by the cells to stay in the mixed layer are a stronger regulator of sedimentation velocity than simply size and temperature.

Unfortunately a sampling problem may have affected the sedimentation velocity results. Discrete water samples on the date of the original trap deployments in April were not collected. As mentioned in the methods, in order to calculate the sedimentation velocity of phytoplankton taxa, the concentration of the taxa found in the trap is divided by the average concentration of the taxa found in the water-column at the beginning and the end of the deployment period. The sediment trap contents collected at the first trap recovery June 2nd seemed to have extremely large concentrations of many of the phytoplankton taxa relative to the phytoplankton present in the May 26/27 or June 2nd discrete water samples. Probably as a result, the sedimentation velocities of these spring taxa may be overestimated. This is one drawback to working with sedimentation traps in the Great Lakes; frequent sampling to avoid this reduced power is difficult.

Regardless of potential errors in sedimentation velocity, it is clear that the sedimentation rates of the many of the species in the Lake Erie phytoplankton community change significantly over the season, and there is also a shift to species

with lower sedimentation velocities and adaptations suited to the smaller mixed depth in the summer months. If P sedimentation rate is directly controlled by diatom sedimentation (Poister and Armstrong, 2003) it should also demonstrate seasonal patterns, mainly a decrease in the summer months during stratification. In Lake Erie, this was indeed the case (Table 5). P sedimentation rate and velocity decreased significantly at both sampling stations from the period of spring mixing to summer stratification followed by an increase upon fall mixing. Therefore, eutrophication models employing annual averages of P sedimentation velocity are flawed for dimictic lakes and do not account for the significant reduction in P sinking from the mixed layer during stratification.

Phosphorus sedimentation dynamics

At station 84 in the central basin, average P sedimentation rate was found to be 1.157 mgP/m^2d and the decline of TP from the epilimnion during stratification was 1.6155 mgP/m^2d (Table 5 and 6). Thus the sedimentation of P in Lake Erie's central basin was almost adequate to account for the decline in TP during the stratified period. This is consistent with Guy *et al.* (1994) who determined that the loss of P from the epilimnion in a number of Ontario lakes was sufficient to account for the P decline.

At station 452 in the eastern basin, P sedimentation rate more than accounted for the decline in TP during the stratified period. The average P sedimentation rate was 1 mg P/m^2d greater than the TP sedimentation rate (Fig. 7). If we assume that the sedimentation traps are accurately catching sedimenting

material, the difference between P sedimentation rate and the decline in TP may be due to littoral or external sources of P (Hudson and Taylor, 2005).

External inputs of P into a basin are often highest in the spring when precipitation is greatest (Wetzel, 2001). Rainfall and snowmelt flowing over the catchment area brings large concentrations of dissolved nutrients to the tributaries where it eventually make their way to the lake. By summer, runoff is usually at a minimum, thus external land inputs of P should be at a minimum as well during the stratified period (Wetzel, 2001). However, the catchment area of Lake Erie is highly agricultural with high density urban areas dispersed throughout. In fact, it is one of the most heavily populated Great Lake catchments (Matisoff and Ciborowski, 2005). Thus, despite a minimum in the summer months, the external input from the catchment may still be a significant source of P. Atmospheric loading should also be a minimum in the summer months and generally comprises less than 10% of Lake Erie's annual P budget (Dolan and McGunagle, 2005).

In total, Dolan and McGunagle (2005) reported tributary loading plus atmospheric loading from 1981-2001 to be 2038.42 metric tonnes per annum for the central basin of Erie and 957.62 metric tonnes per annum for the eastern basin. It is important to note that these amounts are factored into the annual phosphorus budgets of Lake Erie and combined with the point source loads are generally below the 11 000 metric tonnes of P/year target. Thus internal loading may be a more important source of P during stratification.

The importance of internal cycling of P in Lake Erie has been suggested as an explanation for the increasing TP and soluble reactive phosphorus levels despite dramatic reductions in P external inputs. Conroy *et al.* (2005) suggested internal P

load was beginning to become more important in the post-dreissenid period, with significant P sources being released from the sediments during anoxia and P being remineralized by the dreissenids. Studies have found P desorbed from the hypolimnetic sediments to be a significant source of P during stratification in shallow lakes (Bloesch, 1995; Schallenburg and Burns, 2004). However, it seems unlikely that in the deep eastern basin of Lake Erie, P released from the sediments during anoxia would be a significant source of epilimnetic P due to the thick thermal barrier formed during stratification.

Campbell (1994) proposed a model of P regeneration from the shallow epilimnetic sediments for ELA lakes 442 and 373 where P removed from the epilimnion during the beginning of the stratified period is first deposited in the shallow sediments as fish fecal pellets. It is then degraded by microbes and resuspended by wave action, leading to a reintroduction of P back into the epilimnion. In Lake Erie, not only would P be deposited by fish activity, but also by dreissenids who have been shown to transfer substantial amounts of material to the benthos through filtering activity in the form of feces and pseudofeces (Vanderploeg *et al.,* 2001). The deposited material, rich in nutrients, could then be degraded by microbes as well as detritivores who find shelter in the rough-bottom, low-turbulence areas produced by the zebra mussels shells (Hecky *et al.*, 2004). Wave action may then re-suspend PP, and that PP may be transported offshore. It is this re-sedimentation of P that may contribute to the discrepancy between P sedimentation rate and the decline in TP from the epilimnion in the offshore environment.

Nutrient Sedimentation

None of the sedimentation rates of the sediment components included in my study were significantly correlated with each other, with the exception of P with chlorophyll, thus the material sedimenting in Lake Erie was highly variable in composition (Table 6). Average P sedimentation rate was the lowest of the measured components and P also had the lowest average sedimentation velocity (Fig. 10). My literature review found that P sedimentation varies between 0-10 mg P/m^2d with 40% of these lakes having a P sedimentation rate within 0-1 mgP/m^2d (Fig. 1). My calculated values for P sedimentation rate in Lake Erie do indeed fall into this range (Table 6). P sedimentation velocity was also found to exhibit a limited range, with most lakes falling into a range of 1.26 cm/d – 316.22 cm/d (Fig.3). Again, the average P sedimentation velocity for Lake Erie fell within this range (Table 9). When the data in the review was censored to include only values measured during stratification, the range of velocities narrowed to 1.26 cm/d – 125.9 cm/d (Fig. 3). When the average P sedimentation velocity during stratification was calculated for Lake Erie, both stations fell within the narrowed range and were themselves, lower than the annual averages (Table 9). In fact, P sedimentation velocity was found to decrease significantly over the sampling period, until stratification began to break down. These results agree with Poister and Armstrong (2003) who also found that the amount of P reaching the traps in Trout Lake was at a minimum in the summer months.

It appears that P sedimentation velocity decreases in response to a decrease in the depth of the epilimnion brought on by stratification. As mentioned previously, this is mainly due to the phytoplankton community composition

changing to species more adapted to staying in a shallower mixed layer but can also be due to the depletion of nutrients during this period (Hudson and Taylor, 2005). Not only does this apply to a changing epilimnion depth in one lake, but also across lakes that vary in depth. For example, the average P sedimentation velocity for Lake Zug, with a max depth of 64 m in the northern basin and 197 m in the southern basin, was 50-322 cm/d from May to September (Stabel, 1987), while for shallow Mouse and Ranger Lakes P sedimentation velocity was 11.9 cm/d and 12.7 cm/d respectively (Hudson and Taylor, 2005). Therefore, the depth of the mixed layer as well as the change in this depth over the season is an important factor to consider when creating eutrophication models.

P sedimentation velocity and Si sedimentation velocity were positively correlated for Lake Erie in 2004 (Fig. 8). As mentioned earlier, this may indicate the role of diatoms in regulating TP through sedimentation. Rockwell et al. (2005) found an increase in soluble reactive Si since the invasion of the zebra mussels in Lake Erie, with levels reaching well over 1 mg/L in some instances. This increase in the soluble fraction of Si indicates a decrease in diatom abundance, which could potentially lead to a decrease in P sedimentation velocity. Thus, it is possible that the high TP levels observed in the central and eastern basin (Table 5) despite successful reductions in P loading may indicate a reduced P sedimentation velocity resulting from the bioengineering of the ecosystem by the invasive zebra mussel population. As a result, further decreases in P load may be necessary to achieve target levels of TP.

Not only were P and Si sedimentation velocities strongly correlated, the sedimentation rates and velocities of C and N were also strongly correlated (Fig. 8

and 11). In fact, these two nutrients showed the strongest relationship among all the sediment components and both showed no significant difference between their velocities and chlorophyll sedimentation velocity (Table 9). In order to determine the origin of sedimenting material, a C:N ratio is often used (Wetzel, 2001). In the case of Lake Erie, the mean C:N ratio of sediment trap contents was 7.65. Since this is less than 15, it indicates that material sedimenting in the middle of the central and eastern basins of Lake Erie is of primarily autochthonous origin (Wetzel, 2001). This is congruent with the correlations among the sedimentation velocities of C, N and chlorophyll.

In comparison to the sedimentation velocities of P and Si, which are mainly influenced by phytoplankton (more specifically diatom) sedimentation, the sedimentation velocities of C and N were much larger (Table 9). Horn and Horn (1993) found that dead algae and empty diatom frustules sink much faster than live cells, which can actively regulate their density and use motility to reduce their sedimentation velocity. Therefore, the sedimentation rate of C and N may largely represent dead algal cells and material from which P has been lost by remineralization. The relationship between C and N sedimentation velocity with chlorophyll sedimentation velocity further supports this idea since, in this study, chlorophyll included phaeophytin, a degradation product of chlorophyll. In the sediment traps, much of the chlorophyll measured was phaeophytin.

A significant difference was found in the sedimentation velocity of both C and N between the two sampling stations, however no difference was found in the sedimentation rate (Table 6 and 9). The sedimentation velocity of material is often less variable than the sedimentation rate, thus differences in sedimentation velocity

are more likely to be significant. However, for Lake Erie, it does not appear that this was the case as the sedimentation rates of C and N at station 84 were higher than at station 452, while the sedimentation velocities were lower than station 452. It seems more probable that at station 84 there was simply more C- and N-containing material, but this material was slower sinking than that found at station 452.

At station 84, no significant difference was found in the sedimentation rate or velocity of either C or N among the sampling dates (Table 6 and 9). Thus the amount and type of material at station 84 stayed relatively consistent throughout the year. However, at station 452, C sedimentation rate was found to decrease significantly during the sampling period, while both N sedimentation rate and velocity was found to decrease significantly. White and Wetzel (1975) found that N sedimentation rate in Lawrence Lake frequently reflects phytoplankton trends, thus there is a minimum during the summer and a maximum during bloom events. Piña-Ochoa *et al.* (2006) found a correlation between water residence time and the sedimentation of particulate organic nitrogen, likely due to changes in plankton species composition and trophic structure. Thus, at station 452, the community composition is likely regulating N sedimentation dynamics. Despite a lack of significant differences among dates, C sedimentation does decline during the sampling period. Therefore, those factors controlling N sedimentation velocity are likely controlling C sedimentation velocity as well.

As was found for the phytoplankton species, no significant difference with depth was found for any of the sediment component sedimentation rates or velocities measured in Lake Erie (Table 6 and 9). As explained previously, despite

the fact that particle size may increase with depth due to aggregation, increasing porosity with increasing aggregation may stabilize the sedimentation velocity of the individual sediment components.

My results suggest that, for Lake Erie, P and Si sedimentation dynamics are largely influenced by the phytoplankton community composition. C and N sedimentation, however, is much greater indicating these elements represent both live and dead algal cells. Thus, to estimate P sedimentation from mass sedimentation based on Redfield or observed ratios between P and C and N would be misleading. In fact, none of the sedimentation rates obeyed the Redfield ratio for Lake Erie (Fig. 8) and any attempt to model P from C or N would lead to an overestimation of P sedimentation rate.

Comparison of in Laboratory Sedimentation Towers to in lake Sedimentation Traps

Phytoplankton sedimentation

As expected, the sedimentation rates of the phytoplankton calculated via the sedimentation towers were highly variable and included negative sedimentation rates (Table 2). These negative rates illustrate the ability of many species to regulate their position in the water-column, potentially creating a net upward movement of cells.

In general, the tower sedimentation rate measurements were much lower than the trap measurements. For example, at station 84 *Fragilaria* sp. was found to have the highest sedimentation rate of the phytoplankton community by both methods (Table 2 and 3). However the average sedimentation rate calculated via

the traps was an order of magnitude larger than that calculated via the tower. This corresponded with the sedimentation velocity of *Fragilaria* sp. being recorded as much lower for the tower method than for the traps. In general, while the velocities from the two methods were significantly correlated (Figure 6) the trap values were approximately three times larger than those calculated via the towers.

Horn and Horn (1993) also found that velocities determined in laboratory towers were much lower than those determined *in situ*. It is possible that the cells' movements were slowed at the tower walls or that aggregates and cell colonies were broken by any shaking or vibrations during water collection (Horn and Horn, 1993). The July experiments were conducted on board the CCGS Limnos, where vibrations and rolling may have affected the experiment. When the settling velocities calculated in the June experiment are compared to those in the July experiment, there was no overall difference except for the diatoms (Table 4). These had slower settling velocities in July on board the Limnos. A possible explanation could be that the diatoms lack a locomotor apparatus such as flagella or cilia to actively regulate their position in the water column.

Along with experimental error, the community that each method represents may explain the slower sedimentation velocities calculated via the tower experiments. Community composition is dynamic, in response to the dynamic conditions of the lake. The sedimentation traps measure an average sedimentation rate from their time of deployment to the time of sampling (Horn and Horn, 1993). The tower experiments on the other hand, represent a snapshot of the plankton community at the moment of collection. If episodes of high sedimentation are rare, towers may usually underestimate relative to traps.

The estimate of sedimentation velocity via the trap method is derived from the concentration of cells in the trap material collected at the time of sampling, divided by the average concentration of the cells in the water samples collected over this period. In order to be accurate, water samples need to be taken frequently, a difficult task when doing Great Lake studies. The less frequent the water collection, the greater the chance that the mean population during deployment is poorly represented, and events such as blooms or calcite precipitation will be missed. These phenomena will greatly increase the amount of material in the trap, and if not represented in the water samples, the sedimentation velocity of the plankton will be overestimated (Horn and Horn, 1993)

I was not present at the initial trap deployment in April to collect water samples. In fact, my first water samples were not collected until May 26th. Since diatoms are often most abundant during spring mixing, the chance that I missed the maximum abundance is probably large. Therefore, the very high sedimentation velocities calculated at the first trap collection are likely overestimates.

Another possible error in the trap sedimentation velocities is the effects of resuspension (Kozerski, 1994). Horn and Horn (1993) found that algae that are dead sink much faster than those that are alive, mainly because those that are alive have mechanisms to regulate their position in the water column. Thus the trap estimates of sedimentation velocity may be overestimated if they were catching resuspended diatom frustules. Bloesch (1995) suggested that hypolimnetic traps would probably represent both primary and secondary sedimentation, while epilimnetic traps should represent primary sedimentation only. Since my epilimnetic traps were located in the centre of each basin and the central and

eastern basins are relatively large and deep with strong thermal barriers during stratification, it is unlikely that resuspended cells would be caught in these epilimnetic traps (Kozerski, 1994). No significant difference was found in sedimentation velocity with depth for any taxa (Table 3) further indicating that the effects of resuspension on the calculated sedimentation velocity are small.

Another explanation for the larger sedimentation rates calculated via the trap method is that traps in strongly turbulent water can over-trap particles, leading to an overestimation of flux and velocity (Livingstone and Reynolds, 1981). However, Poister and Armstong (2003) determined that for deep Lake Erie, turbulence should not affect trap measurements. This is consistent with Kozerski (1994) who also determined that turbulence in deep lakes has little effect on sediment trap collection.

A final factor to consider is that, according to Stokes Law, warmer temperatures should increase sedimentation velocity of particles since water decreases in viscosity as it becomes warmer (Hutchinson, 1967). This may have been a source of error in the tower experiments, which were conducted in the laboratory at room temperature. Overall, no significant correlation was found between temperature and plankton sedimentation velocity for Lake Erie (Figure 5), which is consistent with Horn and Horn (1993). The effect of temperature is probably small compared to effects of changing species composition, and not detectable in my analysis. Alternatively, any effect by temperature on the individual cells is probably negated by the shift in community composition in response to the changing mixed layer brought on by the change in temperature.

At station 452, *Fragilaria* sp. (Table 1) had the highest sedimentation rate by the sedimentation trap method, but *Rhodomonas lens* (Table 2) was found to have the highest sedimentation rate when calculated via the towers and this species was not even seen in the sedimentation trap material. In fact, there were a few species that were found in the towers that were not seen in the trap material, such as *Chrysochromulina* spp. and *Monoriphidium* spp. Horn and Horn (1993) noted this phenomenon as well, finding species in the free water samples they collected that were not found in the trap contents. This may be due to the fact that these species are so small that they are lost mainly due to grazing. Additionally, they may decompose so quickly in the traps that they are unrecognizable in the trap material under the microscope.

Sedimentation towers may be useful tools for investigations into the sedimentation process of phytoplankton. Not only can they record upward movement, which the traps cannot, but they also eliminate the errors associated with trap sampling, especially when dealing with large lakes where frequent sampling is difficult and overestimations of velocity are likely.

Nutrient Sedimentation

The sedimentation rates and velocities of the nutrients calculated from traps and towers showed no significant correlations (Figure 9 and 12). The sedimentation rates calculated via the traps were always greater than those calculated via the laboratory towers, which were often negative values due to the upward movement of the nutrients with the phytoplankton. An exception was P at station 452 where the tower method resulted in a higher sedimentation rate (Table

6 and 8). This corresponded with a higher sedimentation velocity calculated for P by the tower method (Table 9 and 10). At station 84, Si sedimentation velocity calculated via the towers was also higher than the velocity calculated via the sedimentation traps. All other sediment components had higher sedimentation velocities recorded for the trap method in comparison to the tower method.

As was the case for the phytoplankton sedimentation rates, nutrient sedimentation rates from the traps were representative of a period of time in the lake whereas the towers simply sampled a moment in time (Horn and Horn, 1993). If any events (such as blooms, whitings or resuspension) were not represented in the water samples used in the calculation of sedimentation velocity by the trap method, then velocity would be overestimated. In Lake Erie 2004, no whiting events were recorded, thus this was not the case for this study (Table 7).

Conclusions

The phytoplankton community in Lake Erie was largely diatom-dominated in 2004. These diatoms had the highest recorded sedimentation velocities of the phytoplankton taxa with *Aulacoseira* sp., "other colonial centric diatom spp. " and "large non-colonial centric diatom spp. " having the fastest overall sinking speeds. It is these diatom groups that contribute the most to P sedimentation, as supported by P sedimentation velocity being most strongly related to Si sedimentation velocity (Poister and Armstrong, 2003). No significant variation in sedimentation velocity was found with trap depth, plankton size or temperature, hence the individual plankton cells were employing methods to change their sedimentation velocity in accordance with changing environmental conditions. Not

only were the cells themselves responding to varying conditions, the entire plankton community exhibited shifts towards the slower-sinking taxa *Synedra* sp. and *Fragilaria* sp. during periods of stratification. Therefore, eutrophication models need to take this slower overall sedimentation velocity of the plankton during stratification into account to accurately predict P sedimentation during this time.

Along with dynamic measures of plankton sedimentation velocity, internal loading of P needs to be factored into a successful eutrophication model for Lake Erie. In spite of P sedimentation rate being roughly enough to account for the decline in TP during stratification, TP levels have increased in Lake Erie since the early 1990's (Rockwell et al., 2005; Charlton and Milne, 2004). Since external loading has been drastically reduced since the introduction of the GLWQA (Dolan and McGunagle, 2005) internal loading is likely the answer. It is unlikely that P from deep sediments contributes much to internal loading during stratification due to the thermal barrier, thus P being remineralized and transported from littoral sediments may be the source of this excess P in the pelagic stations of the central and eastern basins. It is possible that the zebra mussels sequester P to the littoral benthos through growth and the production of feces and pseudofeces. This material is eventually re-mineralized by both microbes and detritivores, and returned to the pelagic waters with offshore currents.

Overall, in the offshore waters of Lake Erie, P seems to be largely representative of the living phytoplankton community as indicated by its slow sedimentation velocity. C and N, however, had much faster sedimentation velocities which were most related to chlorophyll sedimentation velocities, chlorophyll being largely comprised of phaeophytin. Thus C and N were probably

representative of fast sinking dead autochthonous material. C, N and P sedimentation rates did not follow the Redfield ratio and, thus, estimation of P sedimentation from mass or C sedimentation is inappropriate for Lake Erie. Direct measurements of P sedimentation rate are instead required.

To measure P sedimentation rate on intra-annual time scales, epilimnetic sedimentation traps seem to be the most accurate as laboratory towers are snapshots in time. However, the towers may be useful tools to compare sedimentation velocities of different phytoplankton species or communities, as upward movement can be recorded. The influence of re-suspended material can be diminished with this method, and the contribution of delicate species not retained in traps can be assessed.

Future Research

It is clear that further sedimentation studies need to be completed for Lake Erie as there are few studies regarding nutrient and planktonic sedimentation dynamics for this Great Lake. This will help to contribute to future eutrophication models that take into account shifting plankton communities during the year and their contributions to P sedimentation. These models are imperative to accurately determine exactly how much P can be safely loaded into the lake without negative consequences.

As I found out, sedimentation trap studies on great lakes are both costly and labour intensive. As a result, frequent sampling of both water and trap contents are difficult to complete leading to possible errors in sedimentation rates. However, these measurements are so vital that a rigorous sampling project with

samples being taken more frequently would give us a much better idea of sedimentation dynamics in Lake Erie. Weekly water samples coupled with biweekly trap samples from the very beginning of ice out through to ice over for one to two years could greatly enhance the knowledge base of sedimentation. Alternatively, Douglas *et al.* (2003) outlined a method for automatic sampling in which a computer operated sampler automatically opens a sampling bottle for a predetermined amount of time. Thus a number of samples can be taken and collected at a later period of time. At any rate, only when we are completely sure of how much P actually sediments out of the system, can we be sure of how much P can be loaded into it.

A possible alternative to whole lake sedimentation trap sampling is a cosmogenic P analysis currently used to determine P residence time in marine systems through the measurement of P radioactive isotopes ^{33}P and ^{32}P (Benitez-Nelson and Karl, 2002). Another alternative is the use of the in laboratory sedimentation towers to accurately calculate the sedimentation velocity of the plankton community. If frequent water samples were taken from the epilimnion of each basin for the entire open water period for a number of years, the response in sedimentation velocity to numerous variables of the specific Lake Erie plankton community could be calculated. Once the response to these variables is finalized, in theory sedimentation could be calculated without physical sampling. Instead, meteorological as well as chemical and thermal data from the lake could be collected and used to predict the sedimentation rate of P.

References

1. Baines, S. B. and Pace M. L. 1994. Relationships between suspended particulate matter and sinking flux along a trophic gradient and implications for the fate of planktonic primary production. Can. J. Fish. Aquat. Sci.; 51:25-38
2. Barbiero, R. P., Rockwell, D.C, Warren, G.J. and Tuchman, M.L. 2006. Changes in spring phytoplankton communities and nutrient dynamics in the eastern basin of Lake Erie since the invasion of *Dreissena* spp. Can. J. Fish. Aquat. Sci. 63: 1549-1563.
3. Benitez-Nelson, C. R. and Karl, D.M. 2002. Phosphorus cycling in the North Pacific Subtropical Gyre using cosmogenic ^{32}P and ^{33}P. Limnol. Oceanogr. 47: 762-770.
4. Bertram, P.E. 1993. Total phosphorus and dissolved oxygen trends in the central basin of Lake Erie, 1970-1991. J. Great Lakes Res. 19: 224-236.
5. Bloesch, J. 1995. Mechanisms, measurement and importance of sediment resuspension in lakes. Mar. Freshwater Res. 46: 295-304.
6. Bolker, B. 2001. Taylor's Power Law – relationship between means and variance. http://www.zoo.ufl.edu/bolker/emd-2001/notes/taylor-power.html. University of Florida.
7. Burns, N.M. and Rosa, F. 1980. In situ measurements of settling velocity of organic carbon particles and 10 species of phytoplankton. Limnol. Oceanogr. 25: 855-864.

8. Campbell, P. 1994. Phosphorus budgets and stoichiometry during the open-water season in two unmanipulated lakes in the experimental lakes area, northwestern Ontario. Can. J. Fish. Aquat. Sci. 51: 2739-2755.
9. Charlton, M.N. and Milne, J.E. 2004. Review of thirty years of change in Lake Erie water quality. NWRI Contribution No. 04-167, Environment Canada, Burlington, ON.
10. Chawla, V.K. 1971. Changes in water chemistry of Lakes Erie and Ontario. In Proceedings of the conference on changes in the chemistry of Lakes Erie and Ontario. pp. 30-64. Bulletin of the Buffalo Society of Natural Sciences 25.
11. Conroy, J.D., Kane, D.D., Dolan, D.M., Edwards, W.J., Charlton, M.N. and Culver, D.A. 2005. Temporal trends in Lake Erie plankton biomass: roles of external phosphorus loading and dreissenid mussles. J. Great. Lakes. Res. 31 (Supplement 2): 89-110..
12. DePinto, J.V., Dolan, D.M. and Lesht, B.M. 2002. Analysis of phosphorus retention in Lake Erie via long-term total phosphorus model. Abstracts 45th Conference on Great Lakes Research. Internat. Assoc. Great Lakes Res.
13. Dillon, P.J and Rigler, F.H. 1974. The phosphorus-chlorophyll relationship in lakes. Limnol. Oceanogr. 19: 767-773
14. Dolan, D.M. 1993. Point source loadings of phosphorus to Lake Erie: 1986-1990. J. Great Lakes Res. 19: 212-223.

15. Dolan, D.M. and McGunagle, K.P. 2005. Lake Erie total phosphorus loading analysis and update: 1996-2002. J. Great Lakes Res. 31 (Supplement 2): 11-22.
16. Droppo, I.G. 2001. Rethinking what constitutes suspended sediment. Hydrol. Process. 15: 1551-1564.
17. Droppo, I.G., Leppard, G.G., Flannigan, D.T. and Liss, S.N. 1997. The freshwater floc: a functional relationship of water and organic and inorganic floc constituents affecting suspended sediment properties. Water Air and Soil Pollution. 99: 43-53.
18. Douglas, R.W., Rippey, B. and Gibson, C.E. 2003. Estimation of the in-situ settling velocity of particles in lakes using a time series sediment trap. Freshwater Biology. 48: 512-518.
19. Ehrhardt, M. 1983. Determination of organic constituents. In Methods of Seawater Analysis, 2nd edition, K. Grasshoff, M. Ehrhardt, and K. Kremling (editors). Weinheim: Verlag Chemie.
20. Fogg, G.E. 1965. Algal cultures and phytoplankton ecology. University of Wisconsin Press, Madison. p 126.
21. Ghadouani, A., and Smith, R.E.H. 2005. Phytoplankton distribution in Lake Erie as assessed by a new *in situ* spectrofluorometric technique. J. Great Lakes Res. 31 (Supplement 2): 154-167.
22. Guildford, S.J., Hecky, R.E., Smith, R.E.H., Taylor, W.D., Charlton, M.N., Barlow-Busch, L. and North, R. L. 2005. Phytoplankton nutrient status in Lake Erie 1997. J. Great Lakes Res. 31: (Supplement 2): 72-88.

23. Guy, M., Taylor, W.D.,Carter, J.C.H. 1994. Decline in total phosphorus in the surface waters of lakes during summer stratification and its relationship to size distribution of particles and sedimentation. Can. J. Fish. Aquat. Sci. 51: 1330-1337.
24. Hanna, M. 1990. Evaluation of models predicting mixing depth. Can. J. Fish. Aquat. Sci.47: 940-947.
25. Hecky, R.E., Smith, R.E.H., Barton, D.R., Guildford, S.J., Taylor, W.D., Charlton, M.N. and Howell, T. 2004. The nearshore phosphorus shunt: a consequence of ecosystem engineering by dreissenids in the Laurentian Great Lakes. Can. J. Fish. Aquat. Sci. 61: 1285-1293.
26. Hiriart-Baer, V. 2003. Supplementary Lab Material BI307 Limnology 2003-2004. Wilfred Laurier University.
27. Horn, H. and Horn, W. 1993. Sedimentary losses in the Reservoir Saidenbach: Flux and sinking velocities of dominant phytoplankton species. Int. Revue ges. Hydrobiol. 78: 39-57.
28. Hudson, J. J. and Taylor W. D. 2005. Phosphorus sedimentation during stratification in two small lakes. Arch. Hydrobiol.: 162:309-325.
29. Huisman, J. and Sommeijer, B. 2002. Maximal sustainable sinking velocity of phytoplankton. Mar Ecol Prog Ser. 244: 39-48.
30. Hutchison, G.E. 1967. A treatise on limnology. Vol II: Introduction to lake biology and limnoplankton. New York: John Wiley and Sons.
31. Kalff, J. 2002. Limnology. Prentice Hall, Uppersaddle NJ.

32. Klerks, P.L., Fraleigh, P.C. and Lawniczak, J.E. 1996. Effects of zebra mussel (*Dreissena polymorpha*) on seston levels and sediment deposition in western Lake Erie. Can. J. Fish. Aquat. Sci. 53: 2284-2291.
33. Kozerski, H-P. 1994. Possibilities and limitations of sediment traps to measure sedimentation and resuspension. Hydrobiologia. 284:93-100.
34. Laroque, I. Mazumder, A., Proulx, M., Lean D.R.S. and Pick, F.R. 1996. Sedimentation of algae: Relationships with biomass and size distribution. Can. J. Fish. Aquat. Sci. 53: 1133-1142.
35. Lean, D.R.S., Fricker, H.J., Charlton, M.N., Cuhel, R.L. and Pick, F.R. 1987. The Lake Ontario life support system. Can. J. Fish. Aquat. Sci. 44: 2230-2240.
36. Livingstone, D. and Reynolds, C.S. 1981. Algal sedimentation in relation to phytoplankton periodicity in Rostherne Mere. Br. Phycol. J. 16: 195-206.
37. Lund, J.W.G., Kipling, C. and LeCren, E.D. 1958. The inverted microscope method of estimating algal numbers and the statistical basis of estimations by counting. Hydrobiologia. 11: 143-170.
38. Matisoff, G. and Ciborowski, J.J.H. 2005. Lake Erie trophic status collaborative study. J. Great Lakes. Res. 31 (Supplement 2): 1-10.
39. Mazumder, A. Taylor W. D. McQueen D. J. Lean D. R. S. 1989. Effects of fertilization and planktivorous fish on epilimnetic phosphorus and phosphorus sedimentation in large enclosures. Can. J. Fish. Aquat. Sci. 46: 1735-1742.
40. Mazumder, A., Taylor, W.D., Lean, D.R.S. and D.J. McQueen. 1992. Partitioning and fluxes of phosphorus: mechanisms regulating the size-

distribution and biomass of plankton. Arch. Hydrobiol. Beih. Ergebn. Limnol. 35: 121-143.

41. Menzel, D.W. and Corwin N. 1965. The measurement of total P in seawater based on the liberation of organically bound fractions by persulfate oxidation. Limnol. Oceanogr. 10: 280-282.
42. Munawar, M. and Munawar, I.F. 1999. The changing phytoplankton biomass and its composition in Lake Erie: a lakewide comparative analysis. In State of Lake Erie: Past Present and Future. M. Munawar, T. Edsall and I.F. Munawar, eds., pp. 125-154. Leiden, The Netherlands: Backhuys Publishers.
43. Nicholls, K.H., Hopkins, G.J. and Standke, S.J. 1999. Reduced chlorophyll to phosphorus ratios in the nearshore Great Lakes waters coincide with the establishment of dreissenid mussels. Can. J. Fish. Aquat. Sci. 56: 153-161.
44. Parsons, T.R. and Strickland, J.D.H. 1963. Discussion of spectrophotometric determination of marine-plant pigments, with revised equations for ascertaining chlorophylls and carotenoids. J. Marine Res. 21: 155-163.
45. Piña-ochoa, E., Alvarez-Cobelas, M., Rodrigo, M.A., Rojo, C. and Delgado, A. 2006. Nitrogen sedimentation in a lake affected by massive nitrogen inputs: autochthonous versus allochthonous effects. Freshwater Biology. 51: 2228-2239.
46. Poister, D. 1995. Effects of the community composition and vertical distribution of phytoplankton on pigment and phosphorus sedimentation in three Wisconsin lakes. PhD. Thesis, University of Wisconsin, Madison.

47. Poister, D. and Armstrong, D.E. 2003. Seasonal sedimentation trends in a mesotrophic lake: Influence of diatoms and implications for phosphorus dynamics. Biogeochemistry. 65: 1-13.

48. Poister, D. and DeGuelle, C. 2005. The influence of particle size distribution and composition on seasonal sedimentation rates in a temperate lake. Hydrobiologia. 537: 35-46.

49. Price, I. 2000. www.une.edu/WebStat. University of New England.

50. Reynolds, C.S. 1986. Experimental manipulations of the phytoplankton periodicity in large limnetic enclosures in Blelheam Tarn. English Lake District. Hydrobiologia. 138:43-64.

51. Reynolds, C.S., Morison, H.R., Butterwick, C. 1982. The sedimentary flux of phytoplankton in the south basin of Windermere. Limnol. Oceanogr. 27: 1162-1175.

52. Rockwell, D.C., Warren, G.J., Bertram, P.E., Salisbury, D.K. and Burns, N.M. 2005. The U.S. EPA Lake Erie indicators monitoring program 1983-2002: trends in phosphorus, silica and chlorophyll a in the central basin. J. Great Lakes Res. 31 (Supplement 20): 23-34.

53. Sakamoto, M. 1966. Primary production by phytoplankton communities in some Japanese lakes and its dependence on lake depth. Arch. Hydrobiol. 62: 1-28.

54. Samuels, M.L. and Witmer, J.A. 1999. Statistics for the Life Sciences, 2nd ed. Prentice Hall, Upper Saddle River. New Jersey.

55. Schallenberg, M. and Burns, C.W. 2004. Effects of sediment resuspension on phytoplankton production: teasing apart the influences of light, nutrients and algal entrainment. Freshwater Biology. 49:143-159.
56. Schwab, D. and Sellers, D. 1996. Computerized bathymetry and shorelines of the Great Lakes. NOAA Data Report ERL GLERL – 16.
57. SCOR/UNESCO. 1966. Working group on photosynthetic pigments. Monographs on oceanographic methodology, Publ, UNESCO 1966.
58. Stabel, H-H. 1987. Settling velocity and residence time of particles in Lake Constance. Schweiz. Z. Hydrobiol. 49: 284-293.
59. Stainton, M.P., Capel, M.J. and Armstrong, A.J. 1977. The chemical analysis of freshwater. Fisheries and Oceans Canada. Special Publication No. 25. Winnipeg, MB.
60. Sommer, U. 1984. Sedimentation of principal phytoplankton species in Lake Constance. J. Plankton Res. 6: 1-14
61. Strickland, J.D.H. 1952. The preparation and properties of silicomolybdic acid (In three parts). J. Am. Soc. 74: 862-876.
62. Strickland, J.D.H. and Parsons, T.R. 1968. A practical handbook of seawater analysis. Bull. Fish. Res. Board Can. 167: 311 p.
63. Sweeny, R.A. 1993. "Dead" Sea of North America? – Lake Erie in the 1960's and '70s. J. Great Lakes Res. 19: 198-199.
64. Thomas, R.H. and J. Walsby. 1985. Buoyancy regulation in a strain of *Microcystis*. J. Gen. Microbiol.131: 799-809.

65. United States Public Health Service. 1965. Report on pollution of Lake Erie and its tributaries. U.S. Department of Health, Education and Welfare. Division of water and pollution control. Washington D.C.

66. Vanderploeg, H.A., Liebig, J.R., Carmichael, W.W., Agy, M.A., Johengen, T.H., Fahnenstiel, G.L. and Nalepa, T.F. 2001. Zebra mussel (*Dreissena polymorpha*) selective filtration promoted toxic *Microcystis* blooms in Saginaw Bay (Lake Huron) and Lake Erie. Can. J. Fish. Aquat. Sci. 58: 1208-1221.

67. Visser, P.M., Massaut, L., Huisman, J. and Mur, L.R. 1996. Sedimentation losses of *Scenedesmus* in relation to mixing depth. Arch. Hydrobiol. 136: 289-308.

68. Vollenweider, R.A. 1968. The scientific basis of lake and stream eutrophication with particular reference to phosphorus and nitrogen as eutrophication factors. 27: 1-182. Technical Report OECD, Paris, DAS/DSI/68.

69. Waite, A., Fisher, A., Thompson, P.A., and Harrison, P.J. 1997. Sinking rate versus cell volume relationships illuminate sinking rate control mechanisms in marine diatoms. Mar. Ecol. Prog. Ser. 157: 97-108.

70. Wetzel, R.G. 2001. Limnology: Lake and River Ecosystems. Third Edition. Academic Press

71. Wetzel, R.G. and Likens, G.E. 1991. Limnological Analysis 2nd ed. Springer-Verlag, New York. P.92.

72. White, W. and Wetzel, R.G. 1975. Nitrogen, phosphorus, particulate and colloidal carbon content of sedimenting seston of a hard-water lake. Int. Verein. Theor. Angew. Limnol. 19: 330-3

Appendix

Appendix 1 - Phytoplankton cell concentrations (cells/mL) in the sediment trap material collected from Lake Erie 2004. Samples include material from both station 84 in the central basin and 452 in the eastern basin.

Station	Date Sampled	Depth (m)	Centric Diatom spp.	"Large Centric Diatom" spp.	*Aulacoseira* sp.	Dinoflagellate spp.	*Plageoselmis nanoplanctica*	*Asterionella* sp.	"Other Colonial Centric Diatom" spp.
84	13-April - 2-Jun	18	47576.000	37059.200	111678.400	0.000	0.000	16025.600	290964.800
84	2-Jun - 21-Jul	18	25040.000	5008.000	1176.000	0.000	0.000	7011.200	1097.600
84	21-Jul - 26-Aug	18	862.400	42.000	10.000	0.000	14.000	6.000	0.000
84	26-Aug - 6-Oct	18	31049.600	12520.000	15524.800	0.000	0.000	28.000	3449.600
84	13-April - 2-Jun	21	33052.800	68108.800	149238.400	0.000	0.000	27043.200	362579.200
84	2-Jun - 21-Jul	21	34555.200	13521.600	22536.000	0.000	0.000	13521.600	5331.200
84	21-Jul - 26-Aug	21	1685.600	1019.200	1646.400	0.000	0.000	40.000	0.000
84	26-Aug - 6-Oct	21	54086.400	22035.200	23036.800	0.000	0.000	40.000	0.000
452	13-April - 2-Jun	20	492787.200	9014.400	27043.200	5008.000	20532.800	627.200	17027.200
452	2-Jun - 5-Aug	20	7261.600	24.000	1058.400	32.000	0.000	262.000	0.000
452	5-Aug - 7-Oct	20	38060.800	8513.600	0.000	0.000	0.000	72.000	0.000
452	13-April - 2-Jun	30	729665.600	18529.600	21033.600	0.000	0.000	2195.200	18529.600
452	2-Jun - 5-Aug	30	12770.400	156.800	509.600	0.000	0.000	2469.600	0.000
452	5-Aug - 7-Oct	30	14022.400	1411.200	0.000	0.000	0.000	40.000	0.000
452	13-April - 2-Jun	40	419169.600	14523.200	23036.800	0.000	0.000	940.800	0.000
452	2-Jun - 5-Aug	40	8513.600	24.000	146.000	0.000	0.000	244.000	32.000
452	5-Aug - 7-Oct	40	12019.200	1724.800	0.000	0.000	0.000	128.000	0.000
452	13-April - 2-Jun	50.7	590944.000	11017.600	10516.800	0.000	0.000	862.400	15524.800
452	2-Jun - 5-Aug	50	10767.200	0.000	627.200	0.000	0.000	1411.200	0.000
452	5-Aug - 7-Oct	50.7	10516.800	28.000	80.000	0.000	0.000	128.000	0.000
Average Station 84			**28488.500**	**19914.250**	**40605.850**	**0.000**	**1.750**	**7964.450**	**82927.800**
Average Station 452			**195541.533**	**5413.933**	**7004.300**	**420.000**	**1711.067**	**781.700**	**4259.467**

Appendix 1 cont…

Station	Date Sampled	Depth (m)	Ciliate spp.	*Diatoma* sp.	Rotifer Eggs	*Synedra* sp.	Cryptomonad spp.	*Dinobryon* sp.	*Gymnodinium helviticum*	*Fragilaria* sp.
84	13-April - 2-Jun	18	0.000	548.800	0.000	0.000	0.000	0.000	0.000	47075.200
84	2-Jun - 21-Jul	18	0.000	392.000	0.000	35556.800	0.000	0.000	0.000	81129.600
84	21-Jul - 26-Aug	18	38.000	0.000	0.000	4.000	2.000	0.000	0.000	3567.200
84	26-Aug - 6-Oct	18	44.000	8.000	4.000	1568.000	0.000	0.000	0.000	61097.600
84	13-April - 2-Jun	21	0.000	0.000	0.000	0.000	0.000	0.000	0.000	125200.000
84	2-Jun - 21-Jul	21	0.000	0.000	0.000	57091.200	0.000	156.800	0.000	266425.600
84	21-Jul - 26-Aug	21	34.000	0.000	0.000	20.000	2.000	0.000	0.000	10016.000
84	26-Aug - 6-Oct	21	88.000	0.000	0.000	352.000	0.000	0.000	0.000	52083.200
452	13-April - 2-Jun	20	470.400	392.000	78.400	0.000	0.000	0.000	0.000	0.000
452	2-Jun - 5-Aug	20	190.000	2195.200	4.000	744.800	22.000	32.000	0.000	36558.400
452	5-Aug - 7-Oct	20	12.000	0.000	0.000	72.000	0.000	0.000	0.000	53585.600
452	13-April - 2-Jun	30	313.600	2430.400	0.000	235.200	9014.400	10016.000	0.000	0.000
452	2-Jun - 5-Aug	30	431.200	5258.400	28.000	3756.000	0.000	0.000	0.000	69360.800
452	5-Aug - 7-Oct	30	48.000	0.000	8.000	60.000	0.000	0.000	0.000	38060.800
452	13-April - 2-Jun	40	0.000	0.000	0.000	0.000	9014.400	0.000	78.400	0.000
452	2-Jun - 5-Aug	40	58.000	1332.800	10.000	705.600	4.000	24.000	0.000	21284.000
452	5-Aug - 7-Oct	40	28.000	0.000	0.000	68.000	0.000	0.000	0.000	21534.400
452	13-April - 2-Jun	50.7	0.000	1646.400	0.000	0.000	0.000	548.800	0.000	0.000
452	2-Jun - 5-Aug	50	162.000	7261.600	0.000	1097.600	0.000	8.000	0.000	31049.600
452	5-Aug - 7-Oct	50.7	0.000	0.000	0.000	4.000	0.000	0.000	0.000	10516.800
Average Station 84			**25.500**	**118.600**	**0.500**	**11824.000**	**0.500**	**19.600**	**0.000**	**80824.300**
Average Station 452			**142.767**	**1709.733**	**10.700**	**561.933**	**1504.567**	**885.733**	**6.533**	**23495.867**

Appendix 1 cont…

Station	Date Sampled	Depth	*Gymnodinium* spp.	*Pediastrum* sp.	*Anabaena* sp.	Pollen	*Ceratium hirundinella*	Green Colonial spp.	*Peridinium* sp.	*Choanoflagellate* sp.
84	13-April - 2-Jun	18	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
84	2-Jun - 21-Jul	18	78.400	0.000	0.000	0.000	0.000	0.000	0.000	0.000
84	21-Jul - 26-Aug	18	0.000	0.000	0.000	0.000	0.000	24.000	0.000	0.000
84	26-Aug - 6-Oct	18	0.000	28.000	0.000	16.000	0.000	0.000	0.000	0.000
84	13-April - 2-Jun	21	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
84	2-Jun - 21-Jul	21	0.000	78.400	0.000	0.000	0.000	0.000	0.000	0.000
84	21-Jul - 26-Aug	21	0.000	4.000	0.000	6.000	0.000	24.000	0.000	0.000
84	26-Aug - 6-Oct	21	0.000	32.000	240.000	0.000	0.000	56.000	0.000	0.000
452	13-April - 2-Jun	20	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
452	2-Jun - 5-Aug	20	68.000	0.000	50.000	14.000	4.000	10.000	0.000	0.000
452	5-Aug - 7-Oct	20	0.000	4.000	56.000	8.000	0.000	68.000	0.000	0.000
452	13-April - 2-Jun	30	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
452	2-Jun - 5-Aug	30	3004.800	0.000	158.000	24.000	2.000	8.000	1252.000	1752.800
452	5-Aug - 7-Oct	30	0.000	0.000	0.000	0.000	0.000	20.000	0.000	0.000
452	13-April - 2-Jun	40	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
452	2-Jun - 5-Aug	40	94.000	0.000	5508.800	4.000	0.000	2.000	14.000	0.000
452	5-Aug - 7-Oct	40	0.000	16.000	0.000	0.000	0.000	1176.000	0.000	0.000
452	13-April - 2-Jun	50.7	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
452	2-Jun - 5-Aug	50	588.000	0.000	50.000	26.000	0.000	2.000	14.000	0.000
452	5-Aug - 7-Oct	50.7	0.000	4.000	0.000	0.000	0.000	72.000	0.000	0.000
Average Station 84			**9.800**	**17.800**	**30.000**	**2.750**	**0.000**	**13.000**	**0.000**	**12.000**
Average Station 452			**312.900**	**2.000**	**485.233**	**6.333**	**0.500**	**113.167**	**146.067**	**5.000**

Appendix 1 cont…

Station	Date Sampled	Depth	*Staurastrum* sp.	Staurodesmus sp.	*Oocystis* sp.	Colonial Rod cyanobacteria	*Tabellaria* sp.	*Microcystis* sp.	Misc. Diatom spp.
84	13-April - 2-Jun	18	0.000	0.000	0.000	0.000	0.000	0.000	0.000
84	2-Jun - 21-Jul	18	0.000	0.000	0.000	0.000	0.000	0.000	0.000
84	21-Jul - 26-Aug	18	2.000	0.000	4.000	8.000	6.000	0.000	0.000
84	26-Aug - 6-Oct	18	48.000	0.000	12.000	0.000	80.000	0.000	0.000
84	13-April - 2-Jun	21	0.000	0.000	0.000	0.000	0.000	0.000	0.000
84	2-Jun - 21-Jul	21	0.000	0.000	0.000	0.000	0.000	0.000	0.000
84	21-Jul - 26-Aug	21	6.000	0.000	0.000	0.000	74.000	0.000	0.000
84	26-Aug - 6-Oct	21	40.000	0.000	0.000	0.000	56.000	0.000	0.000
452	13-April - 2-Jun	20	0.000	0.000	0.000	0.000	0.000	0.000	0.000
452	2-Jun - 5-Aug	20	0.000	0.000	0.000	0.000	0.000	0.000	0.000
452	5-Aug - 7-Oct	20	20.000	8.000	0.000	0.000	0.000	40.000	0.000
452	13-April - 2-Jun	30	0.000	0.000	0.000	0.000	0.000	0.000	0.000
452	2-Jun - 5-Aug	30	4.000	0.000	0.000	0.000	0.000	0.000	0.000
452	5-Aug - 7-Oct	30	8.000	0.000	0.000	0.000	0.000	4.000	0.000
452	13-April - 2-Jun	40	0.000	0.000	0.000	0.000	0.000	0.000	0.000
452	2-Jun - 5-Aug	40	0.000	4.000	0.000	0.000	0.000	0.000	0.000
452	5-Aug - 7-Oct	40	8.000	4.000	0.000	8.000	0.000	56.000	84.000
452	13-April - 2-Jun	50.7	0.000	0.000	0.000	0.000	0.000	0.000	0.000
452	2-Jun - 5-Aug	50	0.000	0.000	0.000	0.000	0.000	0.000	0.000
452	5-Aug - 7-Oct	50.7	20.000	0.000	0.000	32.000	0.000	0.000	12.000
Average Station 84			**12.000**	**0.000**	**2.000**	**1.000**	**27.000**	**0.000**	**0.000**
Average Station 452			**5.000**	**1.333**	**0.000**	**3.333**	**0.000**	**8.333**	**8.000**

Appendix 2 - Phytoplankton concentration (cells/mL) in discrete water samples taken at each sediment trap depth for Lake Erie central (station 84) and eastern (station 452) basin, 2004. Samples represent average concentrations from trap deployment to trap recovery.

Station	Date Sampled	Depth (m)	Centric Diatom spp.	Large Centric Diatom spp.	*Aulacoseira* sp.	*Dinoflagellate* spp.	*Plageoselmis nanoplanctica*	*Asterionella* sp.	"Other Colonial Centric Diatom" spp
84	27-May - 2-Jun	18	0.000	0.020	0.000	0.000	127.704	9.600	0.000
84	2-Jun - 21-Jul	18	455.728	8.308	0.620	0.000	966.544	110.936	0.000
84	21-Jul - 26-Aug	18	911.456	0.060	0.000	0.000	370.592	0.000	0.000
84	26-Aug - 6-Oct	18	0.000	0.000	0.000	0.200	941.504	0.280	0.000
84	27-May - 2-Jun	21	0.000	0.040	4.680	0.000	135.216	9.000	5.500
84	2-Jun - 21-Jul	21	200.320	1.480	0.860	0.000	728.664	79.184	0.000
84	21-Jul - 26-Aug	21	262.920	1.000	14.896	0.000	1795.368	217.652	6.664
84	26-Aug - 6-Oct	21	0.000	0.000	0.000	0.000	380.608	0.360	0.000
452	26-May - 2-Jun	20	334.170	0.540	2.300	15.935	579.790	2.400	0.560
452	2-Jun - 5-Aug	20	26.709	0.000	0.000	23.371	290.464	32.144	0.000
452	5-Aug - 7-Oct	20	95.152	0.120	0.000	0.040	500.800	0.640	0.000
452	26-May - 2-Jun	30	251.083	0.660	6.420	2.504	650.812	2.000	0.260
452	2-Jun - 5-Aug	30	19.577	0.000	0.000	6.222	137.796	13.112	0.000
452	5-Aug - 7-Oct	30	0.000	0.000	0.000	0.000	30.048	0.000	0.000
452	26-May - 2-Jun	40	247.479	0.440	4.420	86.805	516.659	1.600	1.700
452	2-Jun - 5-Aug	40	2.782	0.080	0.133	14.923	77.125	0.947	0.000
452	5-Aug - 7-Oct	40	440.704	1.080	0.240	0.000	190.304	0.000	0.000
452	26-May - 2-Jun	50.7	160.641	0.740	3.800	0.000	424.524	2.120	1.040
452	2-Jun - 5-Aug	50	6.677	0.000	0.133	0.835	53.419	0.413	0.000
452	5-Aug - 7-Oct	50.7	500.800	25.040	0.000	0.000	125.200	0.000	0.000
Average Station 84			**228.803**	**1.364**	**2.632**	**0.025**	**680.775**	**53.377**	**1.521**
Average Station 452			**173.815**	**2.392**	**1.454**	**12.553**	**298.078**	**4.615**	**0.297**

Appendix 2 cont…

Station	Date Sampled	Depth (m)	Ciliate spp.	*Diatoma* sp.	Rotifer Eggs	*Synedra* sp.	Cryptomonad spp.	*Dinobryon* sp.	*Gymnodinium helviticum*	Fragelaria sp.
84	27-May - 2-Jun	18	63.884	0.140	0.000	35.224	10.976	0.000	11.428	67.544
84	2-Jun - 21-Jul	18	16.452	0.000	0.100	25.412	31.320	60.096	13.316	87.024
84	21-Jul - 26-Aug	18	20.950	0.000	0.060	0.160	17.090	50.080	0.000	43.884
84	26-Aug - 6-Oct	18	14.112	0.000	0.120	0.800	26.656	10.016	0.000	115.248
84	27-May - 2-Jun	21	11.516	0.140	0.000	37.888	12.540	0.000	3.000	76.368
84	2-Jun - 21-Jul	21	27.048	0.000	0.040	27.440	38.852	22.536	1.000	119.560
84	21-Jul - 26-Aug	21	23.520	0.000	0.020	1.440	32.536	0.000	0.940	125.440
84	26-Aug - 6-Oct	21	13.328	0.000	0.040	1.440	3.760	0.000	0.040	123.872
452	26-May - 2-Jun	20	0.820	4.120	0.000	0.240	0.380	0.000	0.400	0.000
452	2-Jun - 5-Aug	20	15.096	8.363	0.333	32.821	26.171	0.227	2.107	273.355
452	5-Aug - 7-Oct	20	6.440	0.000	0.000	1.920	8.160	0.000	0.200	42.240
452	26-May - 2-Jun	30	1.540	1.000	0.000	0.160	0.500	0.000	0.380	1.840
452	2-Jun - 5-Aug	30	2.680	1.140	0.067	12.701	1.307	5.021	0.547	96.693
452	5-Aug - 7-Oct	30	0.080	0.000	0.000	0.120	1.280	0.000	0.000	5.080
452	26-May - 2-Jun	40	1.260	0.620	0.000	1.300	0.540	0.020	0.420	0.000
452	2-Jun - 5-Aug	40	0.680	1.307	0.060	2.587	0.840	0.040	0.493	21.069
452	5-Aug - 7-Oct	40	2.320	0.000	0.040	0.000	0.000	0.000	0.000	72.912
452	26-May - 2-Jun	50.7	1.220	0.740	0.000	0.200	0.640	0.000	0.280	1.520
452	2-Jun - 5-Aug	50	0.267	1.027	0.027	1.667	0.333	0.000	0.093	23.200
452	5-Aug - 7-Oct	50.7	13.328	0.000	0.000	0.000	4.480	0.000	0.000	25.872
Average Station 84			**23.851**	**0.035**	**0.048**	**16.226**	**21.716**	**17.841**	**3.716**	**94.868**
Average Station 452			**3.811**	**1.526**	**0.044**	**4.476**	**3.719**	**0.442**	**0.410**	**46.982**

Appendix 2 cont…

Station	Date Sampled	Depth (m)	*Gymnodinium* spp.	*Pediastrum* sp.	*Anabaena* sp.	Pollen	*Ceratium hirundinella*	Green Colonial spp.	*Peridinium* sp.	*Choanoflagellate* sp.
84	27-May - 2-Jun	18	1.240	0.000	0.000	0.000	0.000	0.000	0.000	0.000
84	2-Jun - 21-Jul	18	10.192	0.020	1.860	0.000	0.000	0.000	0.000	0.000
84	21-Jul - 26-Aug	18	0.000	0.040	37.156	0.000	0.960	0.000	0.380	0.000
84	26-Aug - 6-Oct	18	1.680	0.040	62.720	0.000	0.680	0.840	0.000	0.000
84	27-May - 2-Jun	21	0.800	0.000	0.000	0.000	0.000	0.000	0.000	0.000
84	2-Jun - 21-Jul	21	7.920	0.020	0.600	0.100	0.020	0.000	0.000	27.544
84	21-Jul - 26-Aug	21	0.000	0.040	0.140	0.000	0.380	0.000	0.000	42.568
84	26-Aug - 6-Oct	21	0.120	0.000	14.600	0.000	0.080	26.656	0.040	0.000
452	26-May - 2-Jun	20	0.300	0.000	0.000	0.000	0.000	0.000	0.000	0.000
452	2-Jun - 5-Aug	20	2.787	0.000	2.440	0.013	0.027	0.000	0.120	0.000
452	5-Aug - 7-Oct	20	1.000	0.000	31.360	0.000	0.000	30.048	0.000	5.008
452	26-May - 2-Jun	30	1.400	0.000	0.000	0.000	0.000	0.000	0.000	0.000
452	2-Jun - 5-Aug	30	1.120	0.000	0.533	0.013	0.027	0.000	1.120	0.000
452	5-Aug - 7-Oct	30	0.320	0.000	0.000	0.040	0.000	0.000	0.000	0.000
452	26-May - 2-Jun	40	0.960	0.000	0.000	0.000	0.000	0.000	0.000	0.000
452	2-Jun - 5-Aug	40	0.360	0.000	0.000	0.020	0.013	0.000	0.160	0.000
452	5-Aug - 7-Oct	40	0.160	0.000	60.096	0.000	1.120	60.096	0.000	0.000
452	26-May - 2-Jun	50.7	0.780	0.000	0.000	0.000	0.000	0.000	0.000	0.000
452	2-Jun - 5-Aug	50	0.053	0.000	0.000	0.000	0.013	0.000	0.000	0.000
452	5-Aug - 7-Oct	50.7	0.000	0.000	2.680	0.000	0.240	40.064	0.000	0.000
Average Station 84			**2.744**	**0.020**	**14.635**	**0.013**	**0.265**	**3.437**	**0.053**	**8.764**
Average Station 452			**0.770**	**0.000**	**8.092**	**0.007**	**0.120**	**10.851**	**0.117**	**0.417**

Appendix 2 cont…

Station	Date Sampled	Depth (m)	*Staurastrum* sp.	*Staurodesmus* sp.	*Oocystis* sp.	Colonial Rod Cyanobacteria spp.	*Tabellaria* sp.	*Microcystis* sp.
84	27-May - 2-Jun	18	0.000	0.000	0.000	0.000	0.000	0.000
84	2-Jun - 21-Jul	18	0.000	0.100	0.000	0.000	2.200	0.000
84	21-Jul - 26-Aug	18	0.060	27.544	5.008	0.000	0.000	170.272
84	26-Aug - 6-Oct	18	0.000	70.112	10.016	40.064	0.000	1.640
84	27-May - 2-Jun	21	0.000	0.000	0.000	2.504	0.000	0.000
84	2-Jun - 21-Jul	21	0.000	0.020	0.000	0.000	0.960	0.000
84	21-Jul - 26-Aug	21	0.040	0.040	0.040	0.000	3.380	20.032
84	26-Aug - 6-Oct	21	0.000	45.072	0.400	45.072	0.000	10.976
452	26-May - 2-Jun	20	0.000	0.000	0.000	0.000	0.000	0.000
452	2-Jun - 5-Aug	20	0.027	0.053	0.000	1.669	0.000	0.000
452	5-Aug - 7-Oct	20	0.000	95.152	25.040	0.000	0.000	20.032
452	26-May - 2-Jun	30	0.000	0.000	0.000	0.000	0.000	0.000
452	2-Jun - 5-Aug	30	0.000	0.027	0.000	0.000	0.000	0.040
452	5-Aug - 7-Oct	30	0.000	0.000	0.000	0.000	0.000	0.720
452	26-May - 2-Jun	40	0.000	0.000	0.000	0.000	0.000	0.000
452	2-Jun - 5-Aug	40	0.000	0.000	0.000	3.577	0.000	0.000
452	5-Aug - 7-Oct	40	0.000	1.680	0.120	10.016	0.000	50.080
452	26-May - 2-Jun	50.7	0.000	0.000	0.000	0.000	0.000	0.000
452	2-Jun - 5-Aug	50	0.000	0.000	0.000	0.000	0.000	0.000
452	5-Aug - 7-Oct	50.7	0.120	20.032	15.024	10.016	0.000	16.464
Average Station 84			**0.013**	**17.861**	**1.933**	**10.955**	**0.818**	**25.365**
Average Station 452			**0.012**	**9.745**	**3.349**	**2.107**	**0.000**	**7.278**

Appendix 3 - Sediment component concentrations (mg/L) in the sediment trap material for Lake Erie central (station 84) and eastern basins (station 452) in 2004 . Each value represents the mean of triplicate samples.

Station	Date Sampled	Depth (m)	P	C	N	Si	Chlorophyll	Ca
84	13-April - 2-Jun	18	0.933	94.953	10.247	9.258	3.472	1.817
84	2-Jun - 21-Jul	18	0.265	85.039	8.426	7.995	0.444	1.050
84	21-Jul - 26-Aug	18	0.132	118.987	11.557	4.123	0.036	1.655
84	26-Aug - 6-Oct	18	0.804	77.079	8.076	8.129	0.312	1.383
84	13-April - 2-Jun	21	0.986	101.465	11.453	9.878	3.848	2.190
84	2-Jun - 21-Jul	21	0.375	87.800	8.474	9.138	0.727	1.305
84	21-Jul - 26-Aug	21	0.231	80.486	6.765	5.467	0.109	1.227
84	26-Aug - 6-Oct	21	0.995	66.056	7.140	11.577	0.461	1.402
452	13-April - 2-Jun	20	0.858	127.944	16.971	7.283	1.368	1.129
452	2-Jun - 5-Aug	20	0.275	86.651	8.191	5.005	0.132	1.705
452	5-Aug - 7-Oct	20	0.927	60.134	3.520	5.212	0.224	7.948
452	13-April - 2-Jun	30	1.240	132.729	13.733	5.827	1.468	1.595
452	2-Jun - 5-Aug	30	0.288	82.317	7.008	5.166	0.094	2.170
452	5-Aug - 7-Oct	30	0.903	58.620	3.320	7.610	0.173	9.837
452	13-April - 2-Jun	40	0.798	105.624	13.002	7.228	1.343	1.483
452	2-Jun - 5-Aug	40	0.174	92.905	8.292	4.274	0.092	2.209
452	5-Aug - 7-Oct	40	0.558	69.585	4.648	5.942	0.128	9.290
452	13-April - 2-Jun	50.7	0.809	101.244	11.747	7.908	0.821	2.160
452	2-Jun - 5-Aug	50	0.151	90.498	8.079	4.201	0.052	1.332
452	5-Aug - 7-Oct	50.7	0.402	73.305	4.548	6.832	0.076	7.161
Average Station 84			**0.590**	**88.983**	**9.017**	**8.196**	**1.176**	**1.504**
Average Station 452			**0.615**	**90.130**	**8.588**	**6.041**	**0.498**	**4.002**

Appendix 4 - Particulate nutrient concentrations for Lake Erie 2004. Samples were collected in triplicate at each sediment trap depth at both sampling stations. Values included in the appendix represent an average of these triplicate samples from the deployment of the sediment traps to the time of collection.

Station	Date Sampled	Depth	P	C	N	Si	Chlorophyll
84	27-May - 2-Jun	18	11.692	265.000	43.333	54.191	2.567
84	2-Jun - 21-Jul	18	6.006	244.500	54.000	124.998	2.699
84	21-Jul - 26-Aug	18	5.847	318.333	53.000	23.354	3.012
84	26-Aug - 6-Oct	18	5.794	359.750	80.500	70.082	2999.151
84	27-May - 2-Jun	21	9.951	236.167	39.167	53.411	2.616
84	2-Jun - 21-Jul	21	7.669	242.656	39.812	37.626	3.275
84	21-Jul - 26-Aug	21	7.702	282.167	51.500	95.564	3.070
84	26-Aug - 6-Oct	21	5.901	255.250	46.000	77.519	2974.839
452	27-May - 2-Jun	20	5.862	156.833	21.667	55.795	1.974
452	2-Jun - 5-Aug	20	7.382	259.857	48.000	73.219	3.045
452	5-Aug - 7-Oct	20	8.511	176.714	32.429	92.496	2.232
452	27-May - 2-Jun	30	4.498	85.833	10.500	24.433	1.036
452	2-Jun - 5-Aug	30	3.081	80.571	17.714	41.508	1.812
452	5-Aug - 7-Oct	30	2.658	61.429	11.143	53.318	0.859
452	27-May - 2-Jun	40	5.050	68.167	8.667	21.263	0.963
452	2-Jun - 5-Aug	40	2.955	49.000	6.286	14.230	0.359
452	5-Aug - 7-Oct	40	0.844	50.143	10.143	24.589	0.703
452	27-May - 2-Jun	50.7	5.100	56.333	6.500	34.117	0.879
452	2-Jun - 5-Aug	50	1.743	34.667	4.833	12.772	0.169
452	5-Aug - 7-Oct	50.7	1.948	33.857	9.143	84.872	0.209
Average Station 84			**7.570**	**275.478**	**50.914**	**67.093**	**748.904**
Average Station 452			**4.136**	**92.784**	**15.585**	**44.384**	**1.187**

Appendix 5 - Phytoplankton concentrations (cells/mL) in both the top (T) and bottom (B) halves of the specially constructed sedimentation towers for Lake Erie, 2004. Both the central (84) and eastern (452) basins were included. Incubation time was one hour

Stn	Date Collected	Tower	Section	*Plageoselmis nanoplanctica*	*Rhodomonas lens*	Centric Diatom spp.	Heteroflagellate spp.	Nanoflagellate spp.	*Dinobryon* sp.	"Small Cryptomonad" spp.
84	24-Jun-04	1	T	145.232	0	651.04	30.048	1552.48	240.384	140.224
84	24-Jun-04	1	B	125.2	0	856.368	50.08	1201.92	240.384	75.12
84	24-Jun-04	2	T	85.136	0	565.904	50.08	1026.64	160.256	105.168
84	24-Jun-04	2	B	80.128	0	881.408	25.04	1327.12	215.344	115.184
84	21-Jul-04	1	T	350.56	0	671.072	0	1236.976	205.328	160.256
84	21-Jul-04	1	B	255.408	0	490.784	0	951.52	200.32	115.184
84	21-Jul-04	2	T	385.616	0	626	0	1081.728	190.304	160.256
84	21-Jul-04	2	B	280.448	0	370.592	0	1111.776	75.12	70.112
452	22-Jun-04	1	T	0	0	40.064	70.112	2519.024	0	175.28
452	22-Jun-04	1	B	0	0	30.048	50.08	3495.584	15.024	105.168
452	22-Jun-04	2	T	0	0	55.088	85.136	3435.488	50.08	165.264
452	22-Jun-04	2	B	0	0	40.064	35.056	2634.208	45.072	125.2
452	20-Jul-04	1	T	390.624	20.032	45.072	40.064	2028.24	65.104	125.2
452	20-Jul-04	1	B	465.744	25.04	65.104	85.136	2303.68	60.096	130.208
452	20-Jul-04	2	T	320.512	30.048	115.184	30.048	2158.448	55.088	70.112
452	20-Jul-04	2	B	310.496	40.064	75.12	75.12	2273.632	70.112	125.2

Appendix 5 cont…

Stn	Date Collected	Tower	Section	"Large" Cryptomonad sp.	*Chrysochromulina sp.*	Ciliate spp.	*Asterionella* sp.	*Synedra* sp.	*Fragilaria* sp. (large)	*Ceratium hirundinella*
84	24-Jun-04	1	T	0	115.184	1.8	0.84	0.48	1.08	0.04
84	24-Jun-04	1	B	0	60.096	1.2	0.8	0.92	6.08	0.04
84	24-Jun-04	2	T	0	85.136	2.68	1.04	1.24	5.76	0.04
84	24-Jun-04	2	B	0	145.232	1.92	1.16	1.76	15.28	0.08
84	21-Jul-04	1	T	2.32	205.328	1.12	2.36	0.16	4	0.2
84	21-Jul-04	1	B	1.36	175.28	16.464	4.08	0.96	2.88	0.4
84	21-Jul-04	2	T	2.36	85.136	21.168	1.36	0.44	3.16	0.32
84	21-Jul-04	2	B	2.32	75.12	39.984	0.92	0	1.36	0.4
452	22-Jun-04	1	T	0	165.264	0.76	0.6	2.6	12.92	0
452	22-Jun-04	1	B	0	125.2	0.96	1.36	3.24	11.72	0
452	22-Jun-04	2	T	0	150.24	1.44	0.52	2.8	9.24	0
452	22-Jun-04	2	B	0	200.32	1.04	0.76	2.8	9.4	0
452	20-Jul-04	1	T	65.104	230.368	255.408	0.76	0.84	1532.448	0.32
452	20-Jul-04	1	B	0	200.32	60.368	18.032	2.28	367.696	11.76
452	20-Jul-04	2	T	0	205.328	25.088	5.2	1.96	215.6	0.44
452	20-Jul-04	2	B	0	110.176	23.52	5.64	0.96	630.336	0.52

Appendix 5 cont…

Stn	Date Collected	Tower	Section	*Tabellaria* sp.	*Monoriphidium* sp.	*Gymnodinium* spp.	"Large" *Gymnodinium* spp.	*Staurodesmus* sp.	Rotifer egg	*Diatoma* sp.
84	24-Jun-04	1	T	0	0	0	0	0	0	0
84	24-Jun-04	1	B	0	0	0	0	0	0	0
84	24-Jun-04	2	T	0	0	0	0	0	0	0
84	24-Jun-04	2	B	0	0	0	0	0	0	0
84	21-Jul-04	1	T	0.4	0.48	0.6	0	0	0.24	0
84	21-Jul-04	1	B	1.08	0.32	0.68	0	0.2	0.4	0
84	21-Jul-04	2	T	0.8	0.36	1.04	0	60.096	0.28	0
84	21-Jul-04	2	B	0.84	0.28	2.2	0	0.12	0.2	0
452	22-Jun-04	1	T	0	0.16	0	0	0	0	5.4
452	22-Jun-04	1	B	0	0.56	0	0	0	0	9.36
452	22-Jun-04	2	T	0	0.6	0	0	0	0	21.168
452	22-Jun-04	2	B	0	0.64	0	0	0	0	8.24
452	20-Jul-04	1	T	0	0	2.88	0	0	0	0
452	20-Jul-04	1	B	0	0	35.056	4.8	0	0.12	0
452	20-Jul-04	2	T	0	0	0.8	2.04	0	0.08	0
452	20-Jul-04	2	B	0	0	9.04	0	0	0.16	0

Appendix 5 cont…

Stn	Date Collected	Tower	Section	"Large" *Synedra* sp.	*Anabaena* sp.	*Choanoflagellate* sp.	Green Algae spp.	*Peridinium* sp.	*Selenastrum* sp.	*Oocystis* sp.	Green Colonial spp.
84	24-Jun-04	1	T	0	0	0	0	0	0	0	0
84	24-Jun-04	1	B	0	0	0	0	0	0	0	0
84	24-Jun-04	2	T	0	0	0	0	0	0	0	0
84	24-Jun-04	2	B	0	0	0	0	0	0	0	0
84	21-Jul-04	1	T	0	12.32	0	1131.808	0	0	0.12	10.016
84	21-Jul-04	1	B	0	61.936	0	1817.904	0	25.04	0.12	0.36
84	21-Jul-04	2	T	0	86.24	0	2058.288	0	130.208	29.008	0
84	21-Jul-04	2	B	0	82.32	0	1277.04	0	55.088	37.632	19.6
452	22-Jun-04	1	T	0.2	0	0	0	0	0	0	0
452	22-Jun-04	1	B	0.36	0	0	0	0	0	0	0
452	22-Jun-04	2	T	0.36	0	0	0	0	0	0	0
452	22-Jun-04	2	B	0.12	0	0	0	0	0	0	0
452	20-Jul-04	1	T	0	5.08	0	0	0	0	0	0
452	20-Jul-04	1	B	0	66.64	0	1141.824	1.4	0	0	0
452	20-Jul-04	2	T	0	45.472	0	320.512	3.12	0	0	0
452	20-Jul-04	2	B	0	11.24	0	190.304	2.6	0	0	0

Appendix 6 - Nutrient concentrations (ug/L) calculated via the specially constructed sedimentation towers for Lake Erie, 2004. Data is included from both basins, central (84) and eastern (452). T represents the concentration for the top half of the tower and B represents the concentration for the bottom half of the tower. Incubation time was one hour.

Stn	Date Collected	Tower	Section	P	C	N	Si	chlorophyll
84	24-Jun-04	1	T	8.221	18	5	0.3931	0.646
84	24-Jun-04	1	B	9.889	88	20	0.5389	0.621
84	24-Jun-04	2	T	9.736	202	20	0.4413	0.464
84	24-Jun-04	2	B	8.828	251	19	0.4685	0.665
84	24-Jun-04	3	T	9.707	146	13	0.3273	0.525
84	24-Jun-04	3	B	7.361	201	18	0.5115	0.502
84	21-Jul-04	1	T	8.823	263	25	0.3744	3.884
84	21-Jul-04	1	B	11.847	32	2	0.404	3.126
84	21-Jul-04	2	T	10.295			0.4434	3.732
84	21-Jul-04	2	B	9.335			0.3138	3.637
84	21-Jul-04	3	T	10.914			0.4247	4.603
84	21-Jul-04	3	B	11.822			0.4148	2.501
84	26-Aug-04	1	T	4.131	220	34	0.5124	3.902
84	26-Aug-04	1	B	4.999	417	62	0.6022	1.377
84	26-Aug-04	2	T	5.050	276	39	0.45	3.751
84	26-Aug-04	2	B	8.110	338	56	0.3584	3.107
84	26-Aug-04	3	T	5.458	273	53	0.3492	3.902
84	26-Aug-04	3	B	4.591	358	52	0.4619	4.111
84	6-Oct-04	1	T	0.460	245	38	0.6727	4.582
84	6-Oct-04	1	B	0.715	159	35	0.6705	4.582
84	6-Oct-04	2	T	0.511	129	28	0.7783	5.260
84	6-Oct-04	2	B	7.396	275	43	0.6985	4.730
84	6-Oct-04	3	T	7.753	197	41	0.6089	4.582
84	6-Oct-04	3	B	7.906	164	36	0.7543	4.420

Appendix 6 cont…

Stn	Date Collected	Tower	Section	P	C	N	Si	chlorophyll
452	22-Jun-04	1	T	8.291	127	9	0.308	0.551
452	22-Jun-04	1	B	9.524	129	9	0.2651	0.470
452	22-Jun-04	2	T	10.261	110	8	0.2877	0.468
452	22-Jun-04	2	B	10.425	130	9	0.3043	0.498
452	22-Jun-04	3	T	7.393	46	5	0.287	0.602
452	22-Jun-04	3	B	9.716	173	11	0.2499	0.574
452	20-Jul-04	1	T	12.679			0.2885	2.160
452	20-Jul-04	1	B	12.320			0.1977	2.705
452	20-Jul-04	2	T	9.598	10	3	0.43	2.557
452	20-Jul-04	2	B	12.891			0.3772	2.456
452	20-Jul-04	3	T	8.891				3.448
452	20-Jul-04	3	B	12.162			0.3397	2.463
452	26-Aug-04	1	T	5.968	435	44	0.9569	1.402
452	26-Aug-04	1	B	5.866	183	23	1.0224	4.016
452	26-Aug-04	2	T	4.081	141	11	1.5902	1.550
452	26-Aug-04	2	B	8.314	147	21	0.9199	1.595
452	26-Aug-04	3	T	5.407	114	23	0.6643	1.671
452	26-Aug-04	3	B	5.662	168	26	1.6169	1.639
452	7-Oct-04	1	T	7.549			1.0102	3.713
452	7-Oct-04	1	B	5.407	186	32	1.0791	2.741
452	7-Oct-04	2	T	7.447	137	26	1.0937	3.418
452	7-Oct-04	2	B	7.804	152	28	0.9691	2.932
452	7-Oct-04	3	T	11.323	164	32	0.9892	3.492
452	7-Oct-04	3	B	8.008	199	38	1.005	3.021