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The Paleolimnology of Irondequoit Bay: Trophic History Inferred from Sedimentary Diatom Assemblages

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The Paleolimnology of Irondequoit Bay:
Trophic History Inferred from Sedimentary Diatom Assemblages

A Thesis
Presented to the Faculty of the Department of Biological Sciences
of the State University of New York College at Brockport
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Master of Science

by
Anthony L. Verna
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DEPARTMENT OF BIOLOGICAL SCIENCES

REPORT OF COMPREHENSIVE EXAMINATION

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**Introduction**

**Paleolimnology:**

The study of paleolimnology can be most simply defined as the study of lake history. The "mission" of paleolimnology is the reconstruction and interpretation of past environmental conditions from the physical, chemical and biological "evidence" preserved in lacustrine sediments. The past 50 years has seen the maturation of the science of paleolimnology. Improvements in methods and techniques have progressively developed this discipline from a descriptive technique (Pennington 1943, Vallentyne 1955, Round 1961, Stockner and Benson 1967, Bradbury 1975, Stoermer 1977, Brugham 1978, Manny et al. 1978, Lange-Bertalot 1979), to a quantitative science (Brugham 1979, Carney 1982, Stoermer et al. 1985a, Stoermer et al. 1985b, Stoermer et al. 1987, Anderson 1990, Wolin et al. 1991, Stoermer et al. 1993), to a mathematically sophisticated tool of analysis (Prentice 1986, Ter Braak 1986, Line and Birks 1990, Christie and Smol 1993, Yang and Dickman 1993, Yang et al. 1993). The analysis of a continuous record of biological remains in lacustrine sediments has provided valuable insight into the environmental history of many individual lake systems and has led to an increasing data base of information that allows researchers to accurately "back cast" data for which there is no empirical record and to forecast ecosystem behavior by modeling (Dixit, Dixit and Smol 1991, Hall and Smol 1992, Dixit et al. 1993, Pienitz and Smol 1993).

A knowledge of past environmental conditions can be of valuable assistance in determining goals and criteria for remedial programs. The driving force for such programs may be simply from an aesthetic standpoint or what is more important from an economic one such as increased water treatment costs (Forsberg 1987, Reynolds 1987, cited in Anderson et al. 1990).
If perturbation has not been too severe, disturbed ecosystems, by their dynamic nature, may return to previous equilibria if the cause of eutrophication is eliminated (Stockner and Benson 1967, Anderson et al. 1990, Wolin et al. 1991).

Chemical water quality data may indicate rapid return to pre-disturbance conditions. Biological data, particularly diatom stratigraphic profiles, often indicate a much slower response time or the development of a different community structure altogether (Anderson et al. 1990). Shifted equilibria or different community structure at the lowest trophic levels may have great consequences at higher trophic levels resulting in a very different ecosystem than what may be visualized as "pristine" or "ideal". There is the possibility that policy makers, regulatory agencies and the tax paying public may embark on a well meaning and costly remedial plan that does not reflect the "ability" of the subject lake or watershed to respond to or achieve its stated goals.

Irondequoit Bay in Monroe County, New York is a case in point. The bay is a shoreline formation lake, located east of and adjacent to the city of Rochester, New York (Fig. 1). Irondequoit Creek enters the bay from the South and is the major hydrologic input. The outfall of the bay is north, directly to Lake Ontario. Irondequoit Bay, Irondequoit Creek and a number of minor tributaries comprise a drainage basin of 395 km² (Table 1). The bay has been subject to the influences of a growing human population for at least 200 years. Once a very desirable vacation spot known for resorts, boating and fishing opportunities, the bay was severely polluted due to neglect, short-sighted development and poor understanding of ecological principles.

In the past 25 years, much has been done to alleviate the problems that have plagued the bay. The bay has been studied primarily by regulatory agencies (MCPWA 1969, Bubeck 1972, Ellis et al. 1976, MCDOP 1990, Spittal and Burton 1991). Before the early 1970's, data is scant.
Only a few accounts are available from the middle of the century (NYDEC 1940, Tressler et al. 1953, cited in Bannister and Bubeck 1978), and from the early 1900's (Whipple 1913, cited in Bannister and Bubeck 1978). From these studies it is clear that the Irondequoit Bay ecosystem has been severely degraded by human activity.

The major goal of this study was to undertake a paleolimnological survey to determine the character or trophic state of Irondequoit Bay prior to modern records. To what extent has the bay recovered? What are the characteristics of the past and current ecosystems in the bay? Has it returned to its previous equilibrium or is it appreciably different? Have remedial programs been successful? The answers to these questions are goals of this study.

The History of Irondequoit Bay:

In the late summer of 1669, a small group of French explorers under command of the Marquis de LaSalle, turned their canoes inland from Lake Ontario and discovered a well-protected bay. This bay was surrounded by steep forested bluffs. These Frenchmen were the first Europeans to visit what became known as Irondequoit Bay. The name "Irondequoit" can be found in historic accounts dating from 1684, and has been spelled in more than 50 different ways (West 1967). The name has been interpreted from the Mohawk language as meaning "an inlet from the lake" or "a turning aside of the waters". An early map of western New York shows the bay as "Toreonto Bay".

The first European settlement of the watershed began in 1797. This settlement, named "The City of Tryon" by its founder, Salmon Tryon, was never more than a frontier outpost on the banks of Irondequoit Creek. This first settlement served as a short-lived port of call for early fur traders and explorers. Long boats would navigate through Irondequoit Bay and south along
Irondequoit Creek to Tryon located in what is today Ellison Park. Tryon was the site of the first "ashery" and "tannery" in the watershed. Land was cleared for farming and animal husbandry. The City of Tryon therefore, became the first source of pollution in the watershed and set the pattern for the cultural eutrophication of Irondequoit Bay.

The settlement failed and was abandoned in 1818 (Smith 1994). Increasing numbers of settlers found a more suitable harbor along the banks of the Genesee River to the West. The city of Rochester was founded here in 1803 as "Rochesterville". The city of Rochester and its environs became well known as one of the true "boom towns" of the 19th century. By the 1840's some 65% of what is now Monroe County had been "improved". "Improvement" in this sense meant forests were cleared, wetlands drained and soil was turned and tilled for production of crops. By this time there were 13 full time "asheries" in operations, burning trees for the production of charcoal and potash. Several sawmills provided raw material for them as well as lumber for construction (Shanks 1966). These processes led undoubtedly to the silting of Irondequoit Creek and Irondequoit Bay, greatly increasing the loads of nutrient materials such as phosphorus and nitrogen (Bannister and Bubeck 1978). By the middle of the 19th century, the cultural eutrophication of Irondequoit Bay was, quite probably, well underway.

With more and more people enjoying increased free time as a benefit of the industrial revolution, it is easy to understand the increase in the number of resort and amusement facilities that sprang up in aesthetically pleasing places such as Irondequoit Bay. The first hotel on the Bay was a sawmill converted in 1840. In 1865 a renovated home was converted to a lodge for social gatherings and fishing parties. At this time the Bay waters were well known as excellent fishing grounds, and apparently not yet heavily polluted (Smith 1994). By the 1870's a much larger
segment of the population was utilizing the bay for recreation. Several more hotels and campsites were in use and public transportation in the form of large horse drawn wagons and rail lines served the growing number of facilities. These facilities were used by several hundred patrons per day during good weather. There are no records of waste treatment facilities or practices associated with these hotels and resorts. In the 100 years from 1840 to 1940, forty-eight resort hotels were operating at one time or another (Smith 1994).

As the human population increased, the pollution of the watershed from raw sewage increased as well. It is estimated that by 1889 Densmore, Hobie and Thomas Creeks, all tributaries of Irondequoit Bay, were heavily polluted by the raw sewage of 35,000 people (Kuichling 1889, cited in Bannister and Bubeck 1978). The first attempt to alleviate such problems came in 1896 with the building of the first Rochester East Side Interceptor Sewer (Kuichling 1907 cited in Bannister and Bubeck 1978). Rochester's sewer system was a combined storm and sanitary system that, during precipitation events would overflow releasing large loads of raw sewage to Irondequoit Creek, the Genesee River and their tributaries. Near the turn of the century the first primary sewage treatment facilities came on line. The nutrient rich effluent from these plants was discharged directly to Irondequoit Creek and Irondequoit Bay.

By the 1930's, the population of the city of Rochester had reached a plateau and thereafter, decreased (Fig. 3.). The population of the suburban towns in the watershed began to grow rapidly at this time. This caused the overall population in the watershed to continue to increase. As these town populations grew, more treatment plants were built and by the early 1970's an additional 20 plants were on line, discharging an average of 17.22 MGD of treated effluent to the bay and creek (MCHD Engineering Dept., personal communication).
Under the Monroe County Pure Waters Program, new interceptors were built to alleviate the flow of sewage from the city of Rochester's combined sanitary and storm sewers. Most of these overflows were re-routed through the Culver-Goodman tunnel that became operational in 1985 (MCDOP, 1990). An additional network consisting of twenty-six miles of tunnels re-routed effluent from the small package plants discharging to Irondequoit Creek to the newly enlarged and updated Frank E. Van Lare Treatment Plant in Rochester. This new plant was designed for phosphorus removal as well as primary and secondary treatment. This system became fully operational in late 1988 (MCDOP, 1990). The effluent from this facility is discharged offshore in Lake Ontario.

In 1989 and 1990, the Monroe County Health Department undertook a project designed to limit the natural recycling of phosphorus from the sediments of Irondequoit Bay. An alum flocculant was used to seal the sediment water interface, preventing the movement of phosphorus from the sediments into the reducing environment of the anoxic hypolimnion. The goal of this plan was to improve water quality in Irondequoit Bay and to move towards establishing a mesotrophic state based on phosphorus concentrations in the water column. Results from this study have indicated a reduction of phosphorus levels towards target values (Spittal and Burton 1991).

A second major environmental problem that may have changed the characteristics of the Irondequoit Bay ecosystem was the pollution of the bay with heavy runoff of road de-icing salt. The heavy use of salt to maintain bare pavement surfaces began to increase steadily with increases in population and automobile use after the end of World War II. By the winter of 1969-1970, the application of road de-icing salt reached 78,000 metric tons/yr (Diment et al. 1974). Burton (1976) has calculated the amount of salt reaching the bay at 8500 metric tons in 1969, increasing
to 12,500 metric tons in 1974- an increase of 50% in 5 years. This salt load was sufficient to delay spring mixing and in some years prevent complete mixing of the bay waters, i.e., inducing meromixis. These conditions may have profound effects on community structure or seasonal succession patterns among diatom species. High chloride levels in the bay waters may do much to influence dominant species in diatom communities. "Sensible Salting Plans" enacted by watershed communities after 1974 did much to decrease the amounts of salt routinely applied to road surfaces. Winters with heavy snowfall do occur however and application rates increase concomitantly. Application rates in the early 1980's are thought responsible for incomplete mixing of the bay in the spring of 1984 (MCEMC 1987 cited in MCDOP 1990). Chloride levels in Irondequoit Bay may remain as high as four times those routinely measured in the 1950's (Bubeck and Burton 1987). Clearly, based on chloride data alone, water chemistry in Irondequoit Bay would still favor more halophilic species.

The picture that emerges of Irondequoit Bay and its environs is that of a watershed that while clearly an asset to the human community, nevertheless has been severely abused and polluted to a point that it may be unable to recover to predisturbance conditions (Bubeck 1972).

Remedial efforts such as the diversion of sewage, and the restriction of autochthonous phosphorus loading have shown positive results. Along with these results has come an increased interest in recreational usage of the bay. Much new development in the form of marinas and condominiums has occurred in the past 20 years. Boating speed limits are a strong concern to conservationists concerned with shoreline erosion. Fishermen are again using the bay and more commercial and residential development awaits approval from the surrounding town boards.
Are the conservation of Irondequoit Bay and the future of development around the bay compatible? Is there a possibility we will repeat our past mistakes? A paleolimnological survey of Irondequoit Bay can reveal the past to us. Information from this type of survey can increase our understanding of the longer term response of this valuable ecosystem to human activities and be helpful in making more informed decisions about its future.
Materials and Methods

Core Sampling Procedure and Location:

Three cores were taken from the deep basin of Irondequoit Bay, N.Y., latitude 43° 13' 23" N and longitude 77° 32' 7" W (Fig. 1). Samples were taken using a K-B corer (1.85 m x 5.08 cm extruded polycarbonate liner) in 22.9 m of water. The cores were used for diatom analysis, radiometric dating and sediment chemistry respectively. The cores (110, 107 and 98 cm in length) were packed, in ice, inside sections of PVC pipe and transported, upright, to the laboratory for immediate sectioning.

The cores were extruded hydraulically, sectioned at 1 cm intervals and frozen. Radiometric dating of core IB-094-02 using the $^{210}$Pb CIC1 and CIC2 (constant initial concentration) models (Matsumoto 1975, Robbins and Edgington 1975) and the CRS (constant rate of supply) model (Appleby and Oldfield 1978), was done by the Canada Center for Inland Waters laboratory in Burlington, Ontario, Canada. The CIC model assumes a constant sedimentation rate over the time period in which unsupported $^{210}$Pb is measured. The CRS model assumes a variable sedimentation rate. Both models assume a constant flux of unsupported $^{210}$Pb to the sediment/water interface (Turner 1995). The $^{210}$Pb profile of core IB-094-02 was used to determine the chronological age, mean specific gravity, sedimentation rate and mass sedimentation rate of the sediments in Irondequoit Bay. Dates used in this study are those calculated from the CIC1 model.

Diatom Analysis:

From every fourth 1 cm interval, 1 g of wet sediment was digested with concentrated nitric acid for 30 minutes over low heat and continued for an additional 5-10 minutes after a few
crystals of potassium dichromate was added. After cooling, the digested sediments were washed three times with distilled water to remove oxidation products (Patrick and Reimer 1966, Battarbee 1986) and brought to a 50 ml volume.

A 40 μl aliquot of an appropriate dilution (1:3 and 1:4) of sample was delivered by automatic pipette to a cover slip and allowed to dry at room temperature. The cover slips were gently heated and mounted in Hyrax® (Battarbee 1986). Diatoms were identified using several taxonomic keys and guides (Huber-Pestalozzi 1942, Patrick and Reimer 1966, Weber 1971, Patrick and Reimer 1975, Collins and Kalinsky 1977, Pentecost 1984, Dodd 1987), as well as specific research papers (Round 1970, Kalbe 1973, Håkansson and Locker 1981, Stoermer et al. 1981, Theriot and Stoermer 1981, Theriot and Stoermer 1982, Håkansson and Stoermer 1984a, Håkansson and Stoermer 1984b, Stoermer and Håkansson 1984, Håkansson 1986, Kling and Håkansson 1988, Anderson 1990). Valve counts were made with a phase contrast (1000x), oil immersion objective, along two transects with a minimum of 450-500 valves included in each count. Whole valves were counted. Partial and broken valves were only included if diagnostic features allowed clear and definitive identification to the generic level. In many cases, where the valves were well preserved, it was possible to identify valves to the varietal level. In other cases, identification beyond the generic level proved impossible.

**Taxonomy**

The identification of some diatoms in this study proved difficult. The major reasons for difficulty appeared to be: (1) The non-random settling of frustules on the slides which obstructed valves from view; (2) taphonomic effects, the breakage of valves by compaction of the sediments; and (3) Dissolution or partial dissolution of the silica frustule, obscuring or destroying diagnostic
features. This may have been due to either diagenic processes or to the cleaning process. Strong acids (such as HNO3) used in the preparation of samples can destroy delicate spines or other diagnostic features of diatom frustules (Patrick and Reimer 1966; Battarbee 1986).

The identification of species in this study was limited to observation with light microscopy. In recent years, a number of new taxonomic epithets have been proposed by diatom taxonomists. In particular, the genus *Stephanodiscus* has undergone much scrutiny and change (Anderson et al. 1990; Stoermer and Hakansson 1984; Hakansson 1986). It is probable that many of the small forms attributed to *S. hantzschii* in this study could be further differentiated using SEM techniques. Stoermer et al. (1985a) have reported that *S. parvus*, a species common to many small highly eutrophied lakes, is often reported as *S. hantzschii*. *S. parvus* cannot be definitively separated from *S. hantzschii* by light microscopy alone. The autecological characteristics of both species are quite similar, both species being common to heavily eutrophic to hypereutrophic environments. All small forms attributed to *Stephanodiscus* in this study have therefore been referred to as *Stephanodiscus hantzschii*. The overall inferences of trophic state attributed to populations of *Stephanodiscus hantzschii* in this study I believe are valid.

Changes in nutrient concentrations, as well as other environmental changes have been shown to effect cell morphology in diatoms (Schultz 1971; Kalbe 1973; Booth and Harrison 1979; Theriot and Stoermer 1981; Mechling and Kilham 1982). Given that morphological characteristics are a major criterion in diatom systematics, the use of light microscopy may be a limitation to the accurate differentiation of highly variable species occurring in significant numbers within the same samples. The inferences of trophic state do not appear to be greatly affected as these similar species appear in concert with one another and may have similar autecological
requirements or broader tolerances of changing ecological conditions. Such variability in individual forms underscores and emphasizes the complexity and fine structure of ecological systems.
**Results**

**Sediment Dating:**

The $^{210}$Pb profile yielded an age of 150 years for the 107 cm core sample (IB-094-02). The mean specific gravity was determined to be 2.410 gm cm$^{-3}$. The sedimentation rate was calculated to be 2.47 cm yr$^{-1}$ using a CIC model. The average mass sedimentation rate was determined to be 0.17 gm cm$^{-2}$ yr$^{-1}$ (using the CIC1 model), 0.16 gm cm$^{-2}$ yr$^{-1}$ (using the CIC2 model) and 0.17±0.025 gm cm$^{-2}$ yr$^{-1}$ (using the CRS model). A complete chronology of the core is given in Appendix II.

**Species Diversity:**

Species diversity as calculated with the Shannon-Weaver index, not only measures the numbers of species present i.e. species richness, but characterizes the equity of the distribution. Ecologically, equal or similar numbers of two species present in a particular environment reflect the success of both species within that environment. Large numbers of one species accompanied by only a few individuals of a second indicate clear dominance of one species over another. The reasons for this dominance may be varied (Brewer 1979). One reason may be the harshness of the environment, i.e., the degree of pollution present. Calculated values of Shannon-Weaver diversity ($H'$) are greater for communities that exhibit a more equitable distribution of species, or a greater number of niches for a given set of conditions. Index values decrease for communities with fewer niches due to the constraint of polluted conditions.

When compared with the "time line" of events (Fig. 2.), $H'$ values for Irondequoit Bay demonstrate some general trends which may be the result of specific human activity on the
composition of the diatom community since 1850 (Fig. 4.). The greatest diversity \( (H' = 1.38) \) is seen in 1862. Thereafter, the index fluctuates, but overall, it generally declines to its lowest value \( (H' = 0.84) \) in 1924. This period (1862 -1924) is marked by increasing population, pollution of tributaries with domestic wastes, and the advent of resort and recreational use of the bay (Fig. 2.).

Between 1924 and 1942, the index increases from 0.84 to 1.21 to nearly what it was in 1903 (Fig. 4.). This is the largest, short term increase in diversity during the period of time represented by the core sample. Historically, this period is marked by economic depression, resort business decline and failure and a stoppage of population growth in the city of Rochester (Fig. 2.). Swift suburban population growth lags behind by 10-20 years. The total watershed population growth does not halt, but slows down and is seen as a plateau in the total population curve (Fig. 3.).

The period from 1942-1964 represents a period of heavy suburban population growth, infrastructure development, new sewage treatment facilities and industrial growth spurred by World War II (Fig.2.). Diversity index values decrease, then increase slightly again, in general the trend from 1942 to 1964 is one of decreasing diversity. A sharp drop occurs between 1964 (1.12) and 1970 (0.91) (Fig. 4.). This decline to the second lowest diversity index value coincides with the years of heaviest road salt application in the watershed (Fig.2.).

The ten year period from 1970 to 1980 is marked by the second largest, short term increase in the diversity index, 0.91-1.21 (1975) and 1.20 (1980) (Fig. 4.). These years are marked by the end of overall population growth in the watershed and the first measures designed to abate pollution through sewage diversion (Fig. 2.).
From 1985 to 1993, sample intervals are temporally closer. These sediments are less compact and as such give a closer look at the most recent shifts in the diatom community. Between 1980 and 1985, the index drops from 1.2 to 0.96. From 1985 to 1989 it rises to 1.21. The final four years represented by the core (1989-1993) show a decrease in the diversity index from 1.21 to 1.01 (Fig. 4.). In this time period, the major human effects were the completion of sewage diversion and the sediment sealing project undertaken by the Monroe County Health Department (Fig. 2.). After a 9 year period, the index is relatively the same (Fig. 4.).

The overall trend is for a period of decreasing species diversity from 1850 to about 1903 and then a shift to a second period containing large swings about the mean species diversity value of 1.057 from 1913 to the present. The mean species diversity for the period from 1850 to 1903 (1.277), when compared to the mean species diversity for the period from 1913 to 1993 (1.057), using the Mann-Whitney test is significantly higher ($U_{calc}=5.0 < U_{0.05,17,18} = 91$) ($p=0.05$). This suggests, on the whole, a less seriously polluted, i.e., a less productive condition prior to 1903.

**Species Richness:**

Species richness, i.e., the number of taxa present, decreases from 91 to 44 taxa identified per sample from the bottom of the core to the surficial sediments (Fig. 4.). Unlike $H'$ values, there seem to be two significant shifts, rather than one, within the past 150 years in which the diatom flora of the bay changed significantly. The earliest years, 1850 to about 1913, demonstrate the highest numbers of taxa (mean = 77.5), yet a downward trend is apparent (Fig. 4.). The first shift comes between 1913 and 1918 when large loads of sewage from the city of Rochester's east side interceptor and combined overflows entered the bay (Fig. 2.). A second or middle period
from 1918 to 1964 is marked by a relatively stable number of taxa (mean = 64.6) (Fig. 4.). The second large shift occurs between 1964 and 1970 (Fig. 4.). This second shift coincides with the years of heaviest applications of road salt in the Irondequoit Bay watershed (Fig. 2.). These sharp drops in richness may indicate changes which favor the establishment of new flora. The period from approximately 1970 to the present is marked by the lowest levels of species richness in the core (mean = 50.8) (Fig. 4.).

At each of these "shifts", the trend is to a lesser number of taxa, i.e., fewer niches. Fewer numbers of niches may be translated to greater environmental constraints, i.e., a more polluted condition. A statistical comparison of the mean number of species for the three "periods" (1850-1913, 1918-1964 and 1970-1993) using the Kruskal-Wallis test for independence indicates that these periods are significantly different (Hc = 26.0098 > X^2_{0.05,2} = 5.991) (p=0.05).

**Lake Trophic Status Index:**

Many measures of trophic status, based on physical, chemical and biological criteria have been developed in an attempt characterize the limnological attributes of lakes (Nygaard 1949, Rawson 1956, Stockner 1972, Carlson 1977, Yang and Dickman 1993). Many of these indices are based on the phylogenetic relationships and physiologic requirements of diatoms recovered from sediments. The trophic "state" inferred by their presence is usually determined by autecological characteristics derived from studies involving single species.

Yang and Dickman (1993) have proposed a Lake Trophic Status Index (LTSI) based on diatom assemblages from surficial sediment samples and multiple regression analysis of water chemistry parameters taken from a number of lakes in Ontario, Canada. The equation used here and derived from their study is:
LTSI = 2.643 - 7.575 log (Index D) (SE = +/- 0.94).

Where, LTSI = lake trophic status index and index D = (O% + OM % + M %) / (M% + ME% + E%), O = oligotrophic, OM = oligomestrophic, M = mesotrophic, ME = mesoeutrophic and E = eutrophic. The index categories, computed from a regression analysis of TP (total phosphorus), chl-α (chlorophyll-α) and SD (secchi disk depth) data from thirty test lakes are: ultraoligotrophic (LTSI < 0.24), oligotrophic (LTSI = 0.24-1.80), oligomesotrophic (LTSI = 1.81-3.00), mesotrophic (LTSI = 3.01-4.20), mesoeutrophic (LTSI = 4.20-5.40), eutrophic (5.41-9.5) and hypereutrophic (LTSI > 9.5) (Yang and Dickman 1993). The three mesotrophic sub-categories (oligomesotrophic, mesotrophic and mesoeutrophic) are equivalent ranges assigned to the computed overall mesotrophic range (1.81-5.40) (Yang and Dickman 1993). The assignment of species to trophic status categories for Irondequoit Bay was based primarily on existing literature references (Huber-Pestalozzi 1942, Patrick and Reimer 1966, Lowe, 1974, Patrick and Reimer 1975, Patrick 1977, Stoermer 1978, Lange-Bertalot 1979, Stoermer et al. 1985(1-2), Dodd 1987, Yang et al. 1993).

LTSI values calculated for Irondequoit Bay (4.27-9.67) from 1850 to 1993 indicate a long history of eutrophic conditions (Fig 5). LTSI values for the earliest dates from the core are within or very close to mesotrophic values. The index approaches the mesoeutrophic range in 1936, only to increase again and never fall below 6.25 for the rest of the core. The index approaches or surpasses the hypereutrophic boundary in four samples, 1924, 1947, 1970 and 1985. The index falls after 1985, indicating improving conditions, but is still within the eutrophic range. A Spearman Rank-Order correlation of LTSI values with available population figures and dates from the U.S. Census bureau yields a correlation coefficient (r_s) of 0.78 (p = 0.0125) (Fig. 6).
**Centrales to Pennales Ratio:**

Nygaard (1949) developed a quotient index for classifying lake trophic status which relates the numbers of species within the diatom order Centrales to the number of species within the diatom order Pennales. Diatoms were assigned to these orders based primarily on symmetry displayed by the frustule. Centric diatoms are generally circular in outline and display a radial symmetry of surface features about a central point. Pennate diatoms are generally linear or elongate in shape with their surface feature arranged transversely along the valve margins (Weber 1971). This taxonomic scheme has since been revised but the morphological forms are still referred to casually. The C/P ratio is based on the assumption that in oligotrophic lakes, the number of species of pennate form (primarily members of the benthic, epipellic, and epiphytic communities) will outnumber species of centric form (primarily planktonic), yielding low values. Conversely in eutrophic lakes, numbers of centric forms will eliminate pennate forms by decreasing available light due to their large individual populations, yielding larger index values. In Irondequoit Bay, this C/P ratio increases over time, with a range in the index values of 0.16-0.47. The highest index values do occur in the later portions of the core in 1970 and again in 1987-1989 (Fig. 7). In both cases these high values occur after the bay has received large amounts of road salt.

**Diatom analysis:**

A total number of 259 species representing 41 genera were identified from core IB-93-01. A complete listing of all taxa identified and the sample numbers in which each taxon occurs are listed in Appendix III. The occurrence of indicator species and their correlation with historical and


Community Trends:

Using the same five trophic categories as used for calculating the LTSI, the cumulative percentage composition of the diatom flora indicates a trophic history in which eutrophic species represent over 50% of the assemblage much of the time (Fig. 8.). Prior to 1870, mesotrophic species were at their greatest abundance. When combined with mesoeutrophic species percentages and in light of population figures and the extent of human activity in the watershed, the declining trend in levels indicate a changing trophic state from mesotrophy to eutrophy. Between 1880 and 1896, the percentages of both mesotrophic and more pollution tolerant mesoeutrophic species rebound. Truly mesotrophic species do not regain their earlier dominance. The mix of species of differing trophic preference is more evenly distributed. At the turn of the century, a large increase in the percentage composition of eutrophic species occurs. The percentage of the assemblage represented by eutrophic species peaks in 1924 at about 80%. Coincidentally, the LTSI value is 9.51 (within the hypereutrophic range) its second highest throughout the core. During the next 23 years (1924-1947) the percentage of composition of the assemblage shifts toward the mesotrophic range (nearly 40% in 1936) and shifts back again. Eutrophic species lag slightly between 1942 and 1947, but the percentage of mesoeutrophic species increases and fills this "gap" between eutrophic and mesotrophic species. By 1953, eutrophic species are representing over 70% of the assemblage again. From the 1950's to the present, mesoeutrophic species supplant eutrophic species indicating some improvement. A small increase of eutrophic species occurs in 1985, coupled with a relatively greater decrease in...
mesotrophic species. It is during this year that the highest LTSI value (9.67) for the entire core occurs. From 1985 through the present, eutrophic species represent less and less of the assemblage. Mesoeutrophic species are present as approximately 30% of the assemblage. Mesotrophic species represent a similar percentage. In the years between 1987 and 1990, species associated with oligomesotrophic conditions appear as a small percentage of the assemblage. Such species had not been evident since the very early portions of the core.

**Species Composition:**

The species dominating the sediment assemblages in the lower portions of the core (circa 1850-1890), are considered to be indicators of mesotrophic to mesoeutrophic conditions. These species, representing 5-15% each in relative abundance are *Cyclorella bodanica, Asterionella formosa, Fragilaria crotenensis, Tabellaria fenestrata, and Aulacoseira ambiguaj* (Fig. 9.). The mesoeutrophic to eutrophic species *Aulacoseira granulata, Stephanodiscus niagarae* and *Stephanodiscus alpinus* are also present in these proportions (Fig. 10.).

Beginning in the 1880's, the eutrophic to hypereutrophic species *Stephanodiscus hantzschii* becomes more and more dominant, in some samples approaching nearly 60% of the assemblage (Fig. 11.). *S. hantzschii* has long been associated with culturally eutrophicated systems and is widely distributed and firmly established in many of the most polluted areas in the northeastern United States. Along with *S. hantzschii*, other eutrophic indicators make their appearance and increase in importance. At the turn of the century, the eutrophic indicator and halophilic species, *Cyclorella meneghiana* begins to increase from slightly more than 1% of the assemblage to over 15% by 1947 (Fig. 11.). This species remains relatively abundant in modern
times. During the twentieth century, two additional species associated with human disturbance become prevalent. *Diatoma tenue* v. *elongatum* and *Actinocyclus normanii* f. *subsalsa* are considered to be indicators of advanced eutrophication. *A. normanii*, a halophilic species associated with polluted estuaries in Europe, increases rapidly from 1918, reaching peaks above 5% of the assemblage in 1936, 1958-1963, 1975 and 1985. Its greatest abundance came during 1985, approaching 20% of the assemblage (Fig. 11.). *D. tenue* reaches small peaks (4-8%) in 1903 and 1936, a greater peak in 1970 (10%) and rapidly increases to over 20% through the 1980's into the most recently deposited sediments (Fig. 11.). Mesotrophic and mesoeutrophic species stage a resurgence after the 1950's, with *Asterionella formosa*, *Fragilaria crotenensis* and *Stephanodiscus niagarae* all increasing in percentage composition. *Stephanodiscus hantzschii* begins a decline in the 1950's, resurges slightly in the 1980's and rapidly dwindles after 1985 to 3.31% of the assemblage in 1993.

It is interesting to note that among species of very low abundance, those that are considered eutrophic indicators also demonstrate increased percentage composition values between the early 1900's and 1980's. Species such as *Surirella ovata* and *Fragilaria construens*, which appear as only a few valves in each sample early in the core, reach values of 1.5-2% during the 1940's to the 1970's (Fig. 12.). Mesotrophic to mesoeutrophic species of genera such as *Acranthes*, *Cymbella* and *Gomphonema*, which are characteristic of epiphytic or benthic habitats demonstrate generally declining numbers from the bottom of the core to the present (Fig. 12.).

The genus *Navicula*, is by far the most diverse group in Irondequoit Bay, but individual species and their populations are represented by relatively few valves in each sample. Fifty-seven species were identified from the core yet the overall contribution of this genus to the assemblage
varied from 2.38-6.14%. Most species are considered mesoeutrophic to mesotrophic, but tolerant of eutrophic conditions. There is a generally increasing trend in abundance from the 1850's to the turn of the century and a decreasing trend from the 1900's to the present (Fig. 12.). Many more genera and their representative species were identified. A more in depth discussion of the occurrence, contribution to percentage composition and autecological description of the individual species found in the core is given in Appendix I.
Discussion

Trophic History and Human Influence:

It is clear from the analysis of sedimentary microfossil assemblages that the impact of a growing human population has greatly altered the structure of the diatom community of Irondequoit Bay. Changes in the indicator status, species dominance and species abundance are consistent with increasing and relatively rapid eutrophication since 1850. These changes are strongly correlated with the rapid growth of the human population and activity in the watershed.

Measures of diversity within the diatom community of the bay over time demonstrate changes in those communities that are consistent with known observations of biological communities subjected to increasing and decreasing amounts of environmental stress. Between 1862 and 1924, relative species diversity decreased by 38% and the number of species identified dropped from 91 to 56, a 38% decrease as well. This decline coincides with increasing nutrient enrichment from sewage pollution of the watershed (Kuichling 1889).

The earliest sample in the core gives us a look at the trophic state of Irondequoit Bay prior to strong influences from human settlement of the watershed. The LTSI value (4.27) for this sample (1850) suggests that the Bay was in a mesotrophic state (Fig. 5.). The relatively high percentage composition of mesotrophic indicator species present (Cyclotella bodanica-11.35%, Asterionella formosa-9.29%, Aulacoseira ambiguа-12.05%, Fragilaria crotenensis-11.67%) also suggest a mesotrophic state (Fig. 8.). Data from succeeding samples indicate that since the middle of the 19th century, environmental conditions in the Bay have deteriorated. It is important to note that since a mesotrophic state did exist in Irondequoit Bay, as suggested by the data from this study, remediation of the Bay to this earlier trophic status may be possible.
Changes from mesotrophic to eutrophic status, as suggested by the LTSI (Yang and Dickman 1993) occurred shortly after 1850. Between 1850 and 1900, the Bay came under increasingly heavier loads of sewage (Kuichling 1889). This increase in P and N undoubtedly accelerated the eutrophication of Irondequoit Bay. Changes in species dominance reflect this degradation. A relatively diverse and abundant assemblage of mesotrophic species such as *Cyclotella bodanica*, *Tabellaria fenestrata*, *Asterionella formosa*, *Fragilaria crotenensis* and *Aulacoseira ambigu*a represents the largest percentage of the diatom community in the earliest portion of the core. These species are also intolerant of low Si /P ratios caused by advanced nutrient enrichment and subsequent depletion and longer term storage of biogenic silica in the sediments (Schelske *et al.*, 1983; Stoermer *et al.*, 1985b; Anderson *et al.*, 1990). Mesoeutrophic to eutrophic indicator species such as *Aulacoseira granulata* and *Stephanodiscus niagarae* also become abundant species primarily between 1880 and 1900, underscoring the advancing and accelerated eutrophication of the bay. By the early 1900's the higher Si /P adapted species are quickly giving way to a less diverse assemblage dominated by eutrophic to hypereutrophic indicators such as *Stephanodiscus hantzschii*. *S. hantzschii* is adapted to low Si /P ratios and is a late winter / early spring blooming species that quickly utilizes available Si resources during spring circulation (Anderson 1990). Dominance by such species would effectively out compete species less tolerant of low Si /P ratios.

Based on the LTSI (Fig. 5.) and the percentage composition of eutrophic indicator species present (Fig. 8.), by the 1920's Irondequoit Bay was approaching hypereutrophy. This period of time coincides with high population growth in the city, but not in the surrounding towns (Fig. 3.).
The period from approximately 1920-1970 is relatively stable from the standpoint of species richness (Fig. 4.); however, LTSI values indicate a short period of improvement during the 1930's (Fig. 5.). This slight "improvement" appears to be attributed to no singular event or remedial effort, and the sharp downward peak in the LTSI for 1936 appears to be due almost entirely to a sharp increase in the abundance of *Asterionella formosa* (Fig. 9.). Trophic status, as measured by the index, was already trending away from hypereutrophy in 1930 and the index is increasing again in 1942 (Fig. 5.). This "mini recovery" is also reflected by positive shifts in diversity measures between 1936 and 1942 (Fig. 4.). The 1930's was a prolonged period of economic depression. Almost all of the thriving recreational businesses on or near Irondequoit Bay failed or were abandoned (West 1994). The heavy use of these facilities stopped, decreasing or ceasing sewage flow from these sources. The city of Rochester's population peaked and remained relatively constant during the twenty year period between 1930 and 1950. A slowly increasing level of growth in the suburban towns surrounding the bay begins at this time as well, but the overall growth of population in the watershed slows down (Fig. 3.). The decreases in external nutrient load due to slowed growth and disuse of recreational facilities on the bay waterfront may have served to temporarily increase the Si/P ratio in the bay waters, favoring the proliferation of *Asterionella formosa* (Kilham 1971, Tillman 1977); a mesotrophic species.

At the end of the World War II and on into the 1950's the suburban town populations in the watershed begin a 20 year period of renewed growth. The addition of nutrient rich effluents from several new sewage treatment plants in the watershed, renewed industrial growth, and the increased use of phosphate detergents, did much to accelerate the pollution of the bay. By the late 1960's, Irondequoit Bay was receiving discharges serving 150,000 people. During wet weather, a
total of 40,000,000 gallons of combined sewage/day could enter Irondequoit Bay (MCPWA, 1969).

During this same period of renewed population growth and development, heavy use of road salt began. The use of salt for the de-icing of road surfaces is widespread, particularly in the northeastern United States. The use of road de-icing salt on U.S. roads peaked during the 1960's and 1970's (Diment et al. 1974). Figures reported by Diment et al. (1974) estimate the amount of salt applied to U.S. roads during the winter of 1969-1970 at 15.5 million metric tons. The application of salt to the Irondequoit Bay watershed for the same winter was 80,000 metric tons, i.e. approximately 0.5% of the total U.S. application (Diment et al. 1974).

Surface runoff as well as ground water infiltration from road salt application can have serious ecological consequences. The limnological characteristics of lakes can be significantly altered. The density differences between lake waters and salt-laden runoff can delay or inhibit normal circulation patterns, thus affecting recirculation of nutrient materials. Bubeck and Burton (1987) closely studied and documented the physical and chemical limnological changes that occurred in Irondequoit Bay due to the heavy use of road salt in the watershed. Severe changes in mixing patterns, hypolimnion mean temperature, anoxia and chemical reducing conditions, and sustained, four-fold increases in chloride concentration were attributed to the liberal use of de-icing salts in the watershed. Higher chloride concentrations may also serve to stress or inhibit osmoregulatory functions in organisms (Potts 1954). Increased concentrations of sodium ions have been shown to favor the growth of Cyanobacteria, which are indicators of eutrophic conditions (Makarewicz and McKellar 1985). Studies of other lakes and streams have focused on

The great increase in chloride concentration from road salt use as well as the generally increasing concentration of conservative ions from other human influences, has probably affected the structure of the diatom community as seen in my core from Irondequoit Bay. *Cyclotella meneghiniana*, a eutrophic and halophilic species is present in small numbers in the earlier portions of the core. This species increases dramatically during the 1920's and peaks in the middle 1950's, during the first years of increasing road salt use. *C. meneghiniana* remains a major constituent of the diatom community at 10-15% of the assemblage through the middle 1980's. This species declines slightly there after but remains a common diatom at 5-10% of the assemblage through present times (Fig. 11.). A similar increase in the abundance of *C. meneghiniana* and the increase in salt runoff has been documented in a core from Hamilton Harbor, Ontario, Canada (Yang et al., 1993).

A second species common to areas strongly perturbed by human activity and tolerant of increased conservative ion concentrations is *Diatoma tenue v. elongatum*. In Irondequoit Bay, *D. tenue* is present in small numbers (less than 5% of the total assemblage) throughout most of the core. However, in 1970 a sharp increase occurs to over 10% of the community. This coincides with the year of heaviest road salt application to the Irondequoit Bay watershed. The population of *D. tenue* then decreases slightly to 5% of the community in the first half of the 1980's. This may be a response to lower salt applications during the late 1970's. In the late 1980's *D. tenue* increases very dramatically to nearly 25% of the assemblage (Fig. 11.). This may be a response in
part to increased application of salts during the mid 1980's. *D. tenue* is now a major constituent of diatom communities in the more eutrophic areas of the Great Lakes (Stoermer 1978).

A third major halophilic species found in Irondequoit Bay and one of the most pollution tolerant (Stoermer 1978) found in the Great Lakes region is *Actinocyclus normanii f. subsalsa*. This species requires elevated levels of conservative ions for growth. The increased concentrations of such chemical species from sewage pollution and in particular the extensive influx of chlorides and sodium ions from road salt use would favor the growth of this organism. *A. normanii* makes a rather abrupt appearance in the core about 1920 and rapidly increases to between 5 and 10% of the assemblage. *A. normanii* decreases slightly during the late 1930's and 1940's, but resurges and increases dramatically in the late 1960's, the 1970's and into the 1980's when the population peaks in 1985 at nearly 20% of the overall assemblage (Fig. 11.). These years of great increase and dominance coincide well with the years of heavy road salting (Fig. 2.). Of these three halophilic species, *D. tenue* appears to be the largest constituent of the most recent sediments. Many ecological factors may be at work which determine the dominance of one species over another. The trend among these three species, over time, in appearance and increased contribution in numbers to the overall assemblage indicates a major shift in the composition of the diatom community of Irondequoit Bay.

During the years 1978-1980, large reductions in sewage plant discharges to Irondequoit Bay were accomplished by diversion to the upgraded Van Lare treatment plant (MCDOP, 1990). In 1985, with the opening of the Culver-Goodmen Tunnel, a major diversion of combined sewer effluent from Irondequoit Creek and Irondequoit Bay to Van Lare was accomplished. Prior to this date, combined sewage overflows to Irondequoit Bay occurred 50-60 times per year (MCDOP,
By late 1988 an additional 26 miles of interceptor tunnels were diverting sewage to newly expanded facilities at the Van Lare treatment plant (MCDOP, 1990). These Monroe County Pure Waters Programs did much to alleviate the ever increasing load of phosphorus and nitrogen entering the bay. "Sensible Salting Programs" were established by the municipalities in the watershed. These programs initially reduced the amount of additional salt applied to the watershed by 40-60% (MCEMC 1987).

The diatom flora present in the most recent sediments of Irondequoit Bay reflect the changes brought about by sewage diversion. The continued use of road salt appears to be reflected by the persistence of some halophilic species. *Diatoma tenue*, a halophilic, eutrophic indicator remains a major component of the diatom flora since 1985, but *C. meneghiniana* and *A. normanii*, both halophilic species that indicate eutrophic conditions have decreased considerably to below 5% of the sample assemblages. Since sewage diversion, the population of the hypereutrophic indicator *Stephanodiscus hantzschii* has fallen dramatically from 30-40% of the assemblage in the 1970's to below 10 % in the 1990's (Fig. 11.).

Since diversion, eutrophic to mesoeutrophic and mesotrophic species have increased their percentage contributions to sedimentary assemblages. *Stephanodiscus niagarae*, a mesoeutrophic to eutrophic indicator, has increased steadily since the middle portions of the core, suggesting a relaxation of extremely eutrophic conditions (Fig. 9). The mesotrophic species, *Asterionella formosa* has increased from 1-2% in the late 1970's to 5-13% in the 1990's. *Tabellaria fenestrata*, a mesotrophic species, increased slightly from near 0% to 1.5%. *Fragilaria crotenensis*, another mesotrophic species had nearly disappeared from the core by 1920, but has since returned to near 10% of the most recent assemblages (Fig. 9.). It is clear from examining the changes in species
composition of the most abundant species of diatoms, that the Bay has in recent years shifted away from extreme eutrophy or hypereutrophy towards a eutrophic or mesoeutrophic condition.

In 1989 a program to reduce internal phosphorus loading by sealing the sediments with chemical agents was initiated by the Monroe County Health Department. One of the stated goals of the Clean Lakes Project was to return Irondequoit Bay to a mesotrophic state as determined by measurements of phosphorus concentrations and chlorophyll. The results of this study indicate that levels of these indicators of productivity have been reduced since the early 1970's (Spittal and Burton 1991). Target levels for mesotrophy, based on ambient levels of phosphorus and chlorophyll, have not yet been attained. Reduction of hypolimnetic phosphorus is possible by sediment sealing, but further reduction of phosphorus inputs from storm water and surface runoff may be necessary to reach target levels consistent with other mesotrophic bodies of water (Spittal and Burton 1991).

Has Irondequoit Bay returned to mesotrophy? Based on the data from this study it would seem that the Bay has undoubtedly become less eutrophic. However, the most recent diatom deposits indicate an assemblage that is indicative of eutrophic to mesoeutrophic conditions. The presence of sizable populations of halophilic, eutrophic indicators such as *Cyclotella meneghiniana*, *Diatoma tenue* v. *elongatum* and *Actinocyclus normanii* f. *subsa/sa* in these recent sediments is characteristic of some of areas in the Great Lakes basin that are most heavily influenced by anthropogenic events. The appearance of a species such as *Cyclotella comensis* in recent sediment may also be indicative of continuing eutrophy. *C. comensis* has been associated with elevated nitrate levels in Lake Michigan (Stoermer *et al.*, 1985). The slight upward trend in LTSI values between 1991 and 1993 may be evidence that sediment sealing with alum is effective
for only a short duration and the large amount of phosphorus stored in the bay sediments will not be easily contained. Overall species richness is at its lowest in recent sediments. Shannon-Weaver diversity in the most recent sediments ranks 20th of 25 depth intervals sampled. The decrease in populations of small *Stephanodiscus* species such as *Stephanodiscus hantzschii* indicates an improvement but their continued presence argues for a continuing eutrophic environment.

The resurgence of species more indicative of less polluted conditions, such as *Asterionella formosa*, *Fragilaria crotenensis*, *Tabellaria fenestrata*, and *Stephanodiscus niagarae* is encouraging. The appearance of other less abundant yet less pollution tolerant species since the period of sewage diversion is also encouraging. Species such as *Aulacoseira distans* an oligomesotrophic indicator and *A.islandica* an oligotrophic indicator appear in small numbers in more recent sediments.

**Summary:**

The diatom stratigraphy of Irondequoit Bay sediments demonstrates a classic progression of eutrophication in an aquatic ecosystem that has undergone extensive anthropogenic modification. Throughout the 150 year period represented by our core sample, human influence on the trophic status of Irondequoit Bay is clearly evident. Based on the relatively diverse assemblage of diatom remains the Bay was rapidly being transformed from a mesotrophic environment to one of eutrophy as early as the mid 19th century. By the turn of the 20th century, relatively highly diverse communities of mesotrophic to mesoeutrophic species characteristic of benthic, and epiphytic habitats and adapted to higher Si /P ratios were replaced by relatively less diverse communities of increasingly pollution tolerant species characteristic of planktonic habitats and adapted to lower Si /P ratios. These transformations closely follow the increase in human...
population and activities in the watershed. The heavy enrichment of the bay by increasingly heavy loads of phosphorus and nitrogen during the first 75 - 80 years of this century led to extreme or hypereutrophic status. The large increase in conservative ion concentration due to human activity, particularly road salt application in the latter half of this century has strongly changed the character of the diatom community, favoring halophilic species strongly associated with polluted conditions, consistent with similarly effected regions throughout much of the Great Lakes basin. Diatom data supports the positive effects brought about by sewage diversion and remedial efforts such as the sediment sealing. The analysis of diatom assemblages indicates that on the whole, Irondequoit Bay has recovered from its most degraded condition. The structure of the diatom community has changed however and includes significant populations of species such as *Diatoma tenue*, which prefer a saltier environment. Based on this biological assessment of the Bay's longer term ecological past, it is still to be considered a eutrophic to mesoeutrophic body of water.

Remedial efforts to date have demonstrated some positive results. Additional programs will attempt to further reduce nutrient imputs to achieve chosen target nutrient levels (MCDOP 1990). The important point is that Irondequoit Bay's trophic state can be improved. Data from this study indicates that the bay was a mesotrophic body of water in 1850. What should future target levels of P and N be to sustain Irondequoit Bay's previous mesotrophic state? A further and more extensive survey of Irondequoit Bay utilizing advanced paleolimnological techniques, may be of use in future remediation plans. The development of calibration sets with surrounding watersheds and derivation of transfer functions to model or "back cast" ambient nutrient concentrations (P, N) and other environmental parameters (pH) would be useful in the determination of target levels for those nutrients and parameters. Such "empirically" determined
targets may facilitate remediation of the Bay to its "own" mesotrophic state. It would seem that a truly self sustaining, mesotrophic state, based on both chemical and biological criteria is a possibility but has yet to be achieved.
Literature Cited


Kuichling, E. 1889. "Report on the proposed trunksewer for the east side of the City of Rochester, N.Y. made by Emil Kuichling, Civil Engineer, to the Common Council." April 29, 1889 Rochester, N.Y.


Monroe County Environmental Management Council. 1987. The use of road de-icing salt on state roads in Monroe County.


Figure 1. Irondequoit Bay Core Sampling Sites
Figure 2. Time Line of Significant Events Effecting the Irondequoit Bay Watershed
Figure 3. Historical Population Growth in the Irondequoit Bay Watershed
Figure 4. Species Richness and Shannon-Weaver Diversity vs. Time, Irondequoit Bay
Figure 5. Lake Trophic Status Index vs. Time for Irondequoit Bay
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Figure 12. Minor Species Composition
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Figure 14. Genus Synedra and Selected Species
Figure 15. Genus Aulacoseira, Selected Species
Figure 15. Cont. Genus Aulacoseira, Selected Species
Figure 16. Genus Cyclotella, Selected Species
Table 1. Bathymetric Data for Irondequoit Bay

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Data from Bubeck, (1972).
Appendix I: Autecology of the diatoms of Irondequoit Bay.

The identification of diatoms for this study follows the classification scheme used by Patrick and Reimer (1966). They have combined all diatoms into the single class Bacillariophyceae containing nine orders.

**Order Acanthales:** This order is represented by the single family Acanthaceae and two subfamilies, the Cocconeioideae and the Acanthoideae. In Irondequoit Bay sediments these subfamilies are represented by the genera *Cocconeis* (Cocconeioideae), *Acanthnes* and *Rhoicosephenia* (Acanthoideae). The species within the family Acanthaceae are characterized ecologically primarily by their habitat preference. They grow as epiphytes on other algae or aquatic macrophytes. Occasionally they are found in plankton samples but this is usually the result of having been loosened and removed from their substrate, to which they are attached by a gelatinous sheath (Patrick and Reimer, 1966). The genus *Acanthnes* is represented in Irondequoit Bay by 10 distinct species and one species of uncertain affinity. Members of this genus have been classified in autecological studies as mesotrophic to mesoeutrophic indicators (Patrick and Reimer 1966, Yang et al. 1993, Yang and Dickman 1993). Two species of the genus *Cocconeis* and one species of the genus *Rhoicosephenia* were identified.

In general, the genus *Acanthnes* is not a major constituent of the diatom community as determined from the core, ranging from 0-4.35% (Fig. 12). The two most common species are *A. lanceolata* and *A. minutissima*. There is a general trend increasing the proportion of the community represented by this genus in lower levels of the core. This may represent an ecological
trend. Historical records indicate heavy macrophyte growth in the bay near the turn of the century. (Whipple 1912 cited in Bannister and Bubeck 1978).

Species identified for the genus *Cocconeis* were, *Cocconeis placentula* and *C. placentula* v. *euglypta*. *Cocconeis placentula* represents all members of this genus except the single occurrence of *C. placentula* v. *euglypta*. *C. placentula* ranges from 0-1.6% of the diatom assemblage for the levels examined (Fig. 13). This species is considered a mesotrophic indicator (Yang et al. 1993). The upper and lower levels of the core have greater numbers of this species. This minor trend may be indicative of periods of changing trophic status.

The third species of the Acnanthales identified from the sediments is *Rhoicosephenia curvata*. This species is often found in flowing waters, however it is commonly distributed in many lakes in the northeastern United States and is tolerant of a wide range of ecological conditions (Patrick and Reimer 1966). Other workers have classified this species as a eutrophic indicator or placed it in the mesosaprobic category first proposed by Kolkowicz and Marsson (1908) (Yang 1993). *Rhoicosephenia curvata* contributes between 0-0.29% to the samples counted (Fig. 13). Its greatest occurrence is in sample # 012, (1987). There appears to be no significant pattern to its abundance.

**Order Naviculales:** This order contains the largest number of freshwater diatoms as well as many marine species. It is comprised of four families, the Cymbellaceae, the Gomphonemaceae, the Entomoneidaceae and the largest freshwater diatom family, the Naviculaceae. Species in this order are found in a variety of habitats but are most characteristic of the littoral zone and the benthos. They may grow as epiphytes in gelatinous stalks (Cymbellaceae), attached to rocks or other hard substrate (Gomphonemaceae) or on and in the sediments (Entomoneidaceae and
Naviculaceae). Benthic forms may also be motile and may be facultative heterotrophs (Patrick and Reimer 1966, Patrick 1977). The families are comprised of twenty-four freshwater genera representing over thirty thousand recognized species (Patrick and Reimer 1966). The number of species identified from Irondequoit Bay, while not of this magnitude is nonetheless large.

In the Irondequoit Bay core, the family Cymbellaceae is represented by two genera, *Cymbella* and *Amphora*. Sixteen species were identified from the genus *Cymbella* (Appendix III). At all levels of the core, a number of valves were counted as *Cymbella* "species". These valves did not possess sufficient diagnostic features to be identified to the species level. They have been considered as a single "taxon" in the treatment of the data. In all cases the number of such valves is small and error introduced by the lumping of these valves into a single taxon will be minimal compared to considering them to be individual taxa (Brugham 1983). Species of this genus are indicative of a wide range of ecological conditions, ranging from mesotrophic to eutrophic (Patrick and Reimer 1966, Patrick 1977, Yang et al. 1993, Yang and Dickman 1993). *Cymbella* species range from 0-1.95% of the community, with a generally increasing contribution down the core (Fig. 12). *Cymbella cistula*, *C. cymbiformis* and *C. minuta* are the most common species.

The genus *Amphora* is represented almost entirely by the single species, *Amphora ovalis*. Only a single other valve with affinities for this genus occurred in sample # 68 (1913). *A. ovalis* is considered a common mesotrophic indicator species. Although present through much of the core, its contribution to percentage composition is low, ranging from 0-0.65% (Fig. 13).

The family Gomphonemaceae, is well represented in Irondequoit Bay, although its abundance is not relatively large. Seventeen species were identified from the core. Valves of uncertain species affinity were counted as *Gomphonema* "species". The most common species
were *Gomphonema o/ivaceum*, *G. parvulum* and *G. truncatum*. The abundance of *Gomphonema* shows a gradual increase as percentage composition down the core, reaching its maximum relative abundance of 3.42% at 92.5 cm. (Fig. 12). *Gomphonema* species are found over a wide range of environmental conditions, ranging from eutrophic to oligotrophic status (Patrick and Reimer 1966, Lange-Bertelot 1979, Yang *et al.* 1993, Yang and Dickman 1993). Most species appear to prefer mesotrophic to mesoeutrophic conditions. *Gomphonema* species are predominantly epiphytes or benthic dwellers.

The family Entomoneidaceae is represented in the core by two species, *Entomoneis ornata* and *Plagiotropis lepidoptera*. Both are considered mesotrophic to oligomesotrophic species. These species occur in only a few samples. The valves are large complex structures and do not occur in large numbers.

The family Naviculaceae is large and systematically complex. In samples from Irondequoit Bay, this family is comprised of eleven genera represented by seventy-five species and a number of valves of uncertain affinity. The greatest number of species (fifty-seven), belong to the genus Navicula. These species are found in a very wide range of environmental conditions, yet the largest portion of them are commonly found in mesotrophic to mesoeutrophic waters (Patrick 1977). Ten of the eleven genera identified in this study are minor constituents of the diatom communities evident from the core samples.

The genus *Mastogloia* is represented by four species. The first, *Mastogloia smithii* is distributed rather evenly throughout the core. *Mastogloia smithii* *v. lacustris*, *M. grevillei* and *M. elliptica* *v. dansei* are only minor occurrants in the lower levels of the core.
The other species present in the core do not occur with any regularity and any inference of ecological trends from them would be highly speculative. These species are *Gyrosigma accuminatum*, *G. attenuatum*, *Caloneis amphisbaena*, *Amphipleura pellucida*, *Diploneis oculata*, *Diploneis* "species", *Pinnularia stromatophora*, *Pinnularia* "species", *Neidium affine*, *N. dubium*, *N. iridis*, *Anomoneis sphaerophorum*, *A. vitrea*, *Stauroneis smithii*, *Stauroneis* "species" and *Frustulia rhomboides*.

The genus Navicula, due to the large number of species present, is in itself a major component of the diatom communities in the core. This genus is represented by fifty-seven species and a number of "unidentified" valves (Appendix III). The most common species in this group are *Navicula capitata*, *N. cryptocephala*, *N. cryptocephala v. vaneta*, *N. rheinhardtii*, *N. rhyncocephala*, *N. viridula* and *N. tripunctata*. These species appear in all or most samples of the core.

Many more species are present as single occurrences in one or a very few levels of the core. Often, these occurrences are closely related in time, with one or two species appearing and disappearing for short intervals and in no other samples such as *Navicula menisculus v. upsaliensis*, sample #s 72 (1903), 84 (1880), 88 (1870), 92 (1862) and 95 (1850), *N. crucicula*, sample #s 44 (1947) and 48 (1942). In contrast, some species occur sporadically in different levels such as *Navicula decussis*, sample #s 20 (1980), 76 (1896) and 80 (1888) and *N. cincta* sample #s 32 (1964) and 76 (1896).

The contribution of the genus *Navicula* to the overall diatom community is relatively constant. The percentage of composition values range from 2.38-6.14 % (mean 3.36% ±0.19 s.e.). There is a slight increasing trend down the core (Fig 12.).
Order Epithemiales: This order is composed of a single family, the Epithemiaceae. Within the family are three genera, *Denticula*, *Epithemia* and *Rhopalodia*. All three genera were recovered from the core. Members of this order typically grow as epiphytes or attached to rocks or other substrate. They appear to prefer water of moderate to fairly high conductivity. (Patrick and Reimer, 1966).

The genus *Denticula* is represented in the core by one species, *Denticula tenuis*. This species occurs as a few isolated valves in the lower two samples of the core. It is most common in clear flowing waters but does occur in lakes.

The genus *Rhopalodia* is represented by two species, *Rhopalodia gibba* and *R. gibba v. ventricosa*. This genus is common in the northeastern United States and Canada and is usually associated with eutrophic conditions. It appears sporadically throughout the core in small numbers.

Genus *Epithemia* appears as a relatively common epiphytic or epipelic group in most samples. Its relative abundance is low, as are most benthic or littoral epiphytes, but its presence is quite regular (Fig. 13). Its contribution to the overall community structure as seen in the core samples never reaches 1%. The species identified from the core are *Epithemia adnata*, *E. adnata v. minor*, *E. argus*, *E. argus v. longicornis*, *E. turgida* and *Epithemia "species"*. *Epithemia "species"* are valves which are preserved as septa only, with no diagnostic features present on the valve surfaces.

Order Fragilariaceae: This order is represented by the single family, Fragilariaceae. Within this family are eleven genera, seven of which have been identified from the core. The species of this family may be found free living or in filamentous or star shaped colonies as part of the
plankton. Other species are epiphytic on macrophytes of the littoral regions of lakes. Some of these species may be found in the plankton, having been dislodged by wind or wave action (tychoplanktonic). The planktonic species are in general more abundant in core samples than epiphytic or benthic species. This is to be expected, given the more difficult transport of attached species from preferred habitat to the profundal areas of lakes where cores are usually taken. This would also be expected of lakes in an enriched (mesotrophic to eutrophic) condition. Diatom communities from nutrient poor (oligotrophic) lakes, tend to have greater relative numbers of benthic or littoral species, as well as exhibiting lower species diversity (Sherman, 1985).

_Asterionella formosa_ is a common planktonic diatom and has worldwide distribution. It is considered a good indicator of enriched (mesotrophic), conditions. It does occur under a variety of ecological conditions, but is susceptible to limitation by lowering concentrations of silica (Tilman 1977, Anderson et al. 1990.). _A. formosa_ is a common diatom in the core from Irondequoit Bay. It's relative abundance in the core is substantial, (mean 7.84% ± 1.22 s.e.). Its maximum abundance occurs in sample #52 (1936) (Fig. 9).

The genus _Diatoma_ occurs primarily as _Diatoma tenue v. elongatum_. A second species, _D. vulgaré_ is a minor constituent (low relative abundance) that occurs in a number of samples. Both species are considered eutrophic indicators. _D. tenue v. elongatum_ is much more prevalent in the upper part of the core (Fig. 11). It is considered to be indicative of strong anthropogenic influence when it occurs in relatively large numbers and is widely distributed in lake sediments in the most eutrophic sections of the lower Great Lakes basin (Stoermer et al. 1985). Its distribution in Irondequoit Bay samples follows that of sedimentary distributions in the Lakes Erie and Ontario. (Stoermer et al. 1987, and Stoermer et al. 1985).
The greatest diversity within the Fragilariaceae is exhibited by the genus *Fragilaria*. In Irondequoit Bay, this genus is represented by eighteen species identified from the core (Appendix III). The most common species in the core samples are *Fragilaria brevistrata*, *F. capucina*, *F. capucina* v. *mesolepta*, *F. construens*, *F. construens* v. *subsalina*, *F. crotenensis* and *F. pinnata*. With the exception of *F. crotenensis*, these species are primarily benthic or epipelic, often becoming dislocated from their nominal habitats and therefore can be considered tychoplanktonic. *F. crotenensis* is a common planktonic species which forms ribbon-like colonies. It is considered to be a mesotrophic indicator (Yang et al. 1993, Yang and Dickman 1993). This species is a major constituent in the bay diatom community and demonstrates a clear bimodal distribution in the core (Fig. 9).

The genus *Meridion* is represented primarily by the species *Meridion circulare*. This species is indicative of eutrophic conditions (Yang and Dickman 1993). *M. circulare* occurs sporadically throughout the core in very small numbers.

The genus *Synedra* appears in all levels of the core. Valves of several species of *Synedra* are long and in many cases are broken easily. A similar treatment of *Synedra* "species" as a single taxon has been used as in the case of *Cymbella* "species". Many *Synedra* species are indicative of eutrophic waters (Patrick and Reimer 1966, Patrick 1977, Lange-Bertelot 1979, Yang et al. 1993). *Synedra ulna* is the most common species of this genus in the core. Its distribution generally increases up the core, but demonstrates periods of very low relative abundance (Fig. 14). *Synedra* species are known to be sensitive to silica concentrations and episodes of low relative abundance may be indicative of low Si:P ratios which occur in eutrophic waters (Kilham 1971, Schelske 1975, Kilham and Kilham 1990). Other species, more indicative of mesoeutrophic
conditions, *(S. rumpens, S. delicatissima)* reach their greatest abundance in the lower portions of the core (Fig. 14).

The genus *Tabellaria* is represented in the core by two species. The more common of the two is *Tabellaria fenestrata*, a common species considered to be a mesotrophic indicator, but found in mesotrophic to eutrophic waters, and distributed widely across the continental United States (Patrick and Reimer 1966, Yang and Dickman 1993). The second species, *T. flocculosa* appears in only two samples near the bottom of the core. *T. flocculosa* has been associated with a wide variety of water conditions but is primarily considered an oligotrophic to mesotrophic species (Patrick and Reimer 1966).

**Order Eunotiales**: This order consists of the single family Eunotiaceae and has been found only in fresh water (Patrick and Reimer 1966). Only three species were recovered from the core (Appendix III). *Eunotia curvata* was present in only three samples. *Eunotia clevei* and *Peronia intermedium* were present in only a single sample each. Species in this order are characteristic of waters of low nutrient and mineral content (oligotrophic-dystrophic). Their extreme scarcity in Irondequoit bay is therefore not surprising.

**Order Surirellales**: In Irondequoit Bay sediments, this order is represented by a single family, the Surirellaceae and two genera, *Surirella* and *Cymatopleura* (Appendix III). Six species of Surirella were identified. The two most common being *Surirella ovata* and *S. angusta*. *Cymatopleura solea* was the only member of it's genus identified. Species of the genera *Surirella* and *Cymatopleura* are often found in the benthos as well as the plankton and both genera are commonly found in nutrient enriched conditions (Huber-Pestalozzi 1942, Patrick and Reimer 1966, Lange-Bertalot 1979, Yang *et al.* 1993, Yang and Dickman 1993). *Surirella ovata*, a spring
blooming, cold water form with affinity for moderate to organically polluted waters reaches its greatest relative abundance in the middle to upper third of the core (Fig. 12).

Order Bacillariales: This order is represented in Irondequoit Bay by the single family, the Nitzschiaeae. The genera *Nitzschia* and *Hantzschia* were identified from the core. The identification of species in the genus *Nitzschia* proved most difficult due to the condition of many valves and the similarity of diagnostic features. This genus was the second most diverse group in the core. A total of thirty-four species were identified (Appendix III). Most of these species occurred as a single valve in one or two samples. Three *Nitzschia* "species" appeared in the sediments that could not be satisfactorily identified, giving a total of thirty-seven "taxa". Two of these occurred in most samples. The most common species were *Nitzschia amphibia*, *N. dissipata*, *N. linearis*, *N. palea*, *N. capitellata*, *Nitzschia* "species" 1 and *Nitzschia* "species" 2. Species of the genus *Nitzschia* are extremely diverse in habitat preference, being found in the benthos, the plankton, the neuston, as epiphytes and in some cases as aerophiles (Patrick and Reimer 1966). They are also indicative of enriched (mesotrophic) to heavily, organically polluted (hypereutrophic) waters and have been used as indicators of varying degrees of pollution in European river systems (Lange-Bertalot 1979). As a genus, *Nitzschia* contributes between 1 and 4 % to the diatom communities seen in the core (mean 1.82 ± 0.16 %). It reaches its greatest abundance in the middle portion of the core (Fig. 13).

The genus *Hantzschia* occurred as only a few valves in four samples (Appendix III). Its ecological implications are therefore unclear from this study.

Order Eupodiscales: This order contains diatoms of fundamentally different morphology. These organisms possess radial symmetry as opposed to the basically bilateral arrangement of all
other orders discussed. The Eupodiscales are primarily planktonic, living as solitary cells or filaments. The major constituents of the core belong to this order.

The order is represented in Irondequoit Bay by the single family Coscinodiscaceae. Within this family, five genera were isolated. The systematics of this order and family are quite complex and much disagreement still exists regarding affinities of individual species. The identification of these species in general follows the schemes of several authors, but in conflicting cases, more weight is given to research associated with samples and specimens associated with the Great Lakes.

The genus Actinocyclus is represented by the single species \textit{A. normanii f. subsalsa}. It is a rather large diatom and is easily identified. Most species of this genus are marine. \textit{A. normanii} is common in recent sediments in the Great Lakes basin and displays affinity for waters of high conductivity, salt concentration and generally polluted conditions (Stoermer et al. 1987). Its increase in abundance in Irondequoit Bay appears to coincide well with increasing anthropogenic effects such as nutrient loading from sewage and road salting (Fig. 11).

The genus Thalassiosira is represented by the single species \textit{T. fluviatus} and is present in only a single sample. No ecological inferences can be attributed to its presence.

The remaining three genera of the Coscinodiscaceae, \textit{Aulacoseira, Cyclotella} and \textit{Stephanodiscus}, provide a great deal of information regarding the past ecological conditions in the bay. Species of these genera have affinities for a large range of conditions and the changes in abundance patterns demonstrated from the core sheds much light on longer term trophic status of the bay.
Ten species of the genus *Aulacoseira* were identified from the core (Appendix III). The mesoeutrophic species *A. ambigua* (Yang et al. 1993) and the eutrophic indicator species *A. granulata* (Yang et al. 1993) are the most abundant members of this genus. They are present in most samples but their greatest abundance occurs in the lower portions of the core. They are common species in summer and in autumn preferring warmer temperatures and relatively moderate amounts of silica (Huber-Pestalozzi 1942, Stoermer et al. 1987). Their abundance declines in the middle portions of the core and increases toward the surface layers, never regaining their earlier high proportions. The genus is more diverse in the upper parts of the core, with the oligotrophic species, *A. islandica* (Stoermer et al. 1987, Yang et al. 1993) and the oligomesotrophic species, *A. distans* (Yang et al. 1993) present in small numbers as well (Fig 15).

Seven species of the genus *Cyclotella* were identified from the core samples. Of these, *C. meneghiniana*, a halophilic and eutrophic indicator (Stoermer 1978, Yang et al. 1993) and *C. bodanica*, a mesotrophic indicator (Yang et al. 1993), are the most common and give clear indications of shifts in trophic status over the time period covered by the core (Fig 16). Another species which is more common to the recent flora of the Great Lakes (Stoermer et al. 1985), *C. comensis* is present in relatively significant numbers in the upper portion of the core. *C. michiganiana* appears sporadically in the core. It is most often associated with nutrient poor environments and is characteristic of offshore areas in the upper Great Lakes (Stoermer et al. 1985).

The genus *Stephanodiscus* is a major component of the diatom flora of Irondequoit Bay. Species of this genus are most often associated with nutrient enriched waters (Huber-Pestalozzi
1942, Patrick 1977, Stoermer et al. 1985, Yang et al. 1993). The two species, *S. niagarae* and *S. hantzschii*, are the two most common species in the core. The distribution of abundance patterns of these two species throughout the core are indicative of the long history of eutrophic conditions which have characterized Irondequoit Bay for at least the last century. The largest percentages of diatom abundance which occur are due to the presence of the single species *S. hantzschii*. This species is enigmatic in that several small *Stephanodiscus* forms appear to be related. Much discussion can be found in the literature, considering the taxonomic relationships of these small forms (Theriot and Stoermer 1982, Håkansson and Stoermer 1984, Stoermer and Håkansson 1984, Håkansson 1986, Anderson 1990). This variability of form can be found in Irondequoit Bay samples as well and proved to be a source of difficulty in the identification procedure. For the purposes of this study, these small forms (5-10μ diameter) are referred to as *S. hantzschii*. Further delineation was not possible with light microscopy. Similar studies have shown that these related small forms, as well as the species *S. hantzschii*, are strong indicators of anthropogenic effects in several lakes in the Great Lakes basin, as well as other parts of the world (Bradbury 1975, Stoermer 1978, Stoermer et al. 1985, Stoermer et al. 1987, Carney 1982, Anderson 1990).
## Appendix II

### Pb 210 Chronology for core IB-94-02

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* Dates were determined by a sedimentation rate calculated from Pb 210 analysis by the Canadian Center for Inland Waters laboratory.

** Dates prior to 1878 are estimates due to undetectable Pb 210 activity and assuming a constant sedimentation rate of 2.47 cm/yr.
Appendix III

Diatom Species Identified from Irondequoit Bay

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<td>4,8,12,16,20,24,28,32,36,40,44,48,68,72,80,84</td>
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<td><em>Caloneis amphisaena</em> (Bory) Cleve.</td>
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<td>8,12,20,44,64</td>
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<td><em>Cocconeis placentula</em> Ehr.</td>
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<td><em>C. placentula v. euglypta</em> (Ehr.) Cleve.</td>
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<td><em>Cyclotella bodanica</em> Eulnst.</td>
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<td><em>C. comensis</em> Grun.</td>
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<td>1,4,8,12,16,20,28,32,36,48,92,95</td>
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C. krammeri (Thw.) Hakans. P 52,76
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C. michiganiana Skv. P 1,8,12,16,20,24,28,40,60,64,88,92,95
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C. minuta v. latens B,E 20,84,88,95
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F. capucina Desm.  
F. capucina v. meso/pola Rabh.  
F. constricata Ehr.  
F. construens (Ehr.) Grun.  
F. construens v. binodis  
F. construens v. pumilia Grun.  
F. construens v. subsalina  
F. construens v. venter (Ehr.) Grun.  
F. crotonensis Kitton  
F. intermedia  
F. lapponica Grun.  
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F. pinnata (Ehr.)  
F. pinnata v. intercedens Grun.  
F. pinnata v. lance tulia (Scum.) Hust.  
F. vaucheriae (Kutz.) Peters  
F. virescens Ralfs  
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Gomphonema acuminatum Ehr.  
G. affine Kuetz.  
G. angustatum (Kuetz.) Rabh.  
G. brebesonii  
G. dichotomum  
G. gracile Ehr. emend. V. H.  
G. intricatum  
G. olivaceum (Lyngb.) Kuetz.  
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G. subclavatum v. commutatum  
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Gyrosigma accuminatum (Kutz.) Rabh.
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Mastogloia elliptica v. danseii (Thwaites) Cl.
M. grevellei W. Sm.
M. smithii Thwaites ex W. Sm.
M. smithii v. lacustris Grun.
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M. circulare v. constrictum (Ralfs) V. H.
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N. amphibia Cl.
N. anglica Ralfs
N. arvensis Hust,
N. aurora Sov.
N. bacillum Ehr.
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N. capillata Ehr.
N. capillata v. hungarica (Grun.) Ross
N. cincta (Ehr.) Kutz.
N. crucicula (W. Sm.) Donkin
N. cryptocephela Kutz.
N. cryptocephela v. veneta (Kutz.) Rabh.
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N. decussis Ostr.
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N. minima Grun.
N. minuscula Grun.
N. mournei Patr.
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<td><em>N. pupula v. rectangularis</em> (Greg.) Grun.</td>
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<td><em>N. pygmaea</em> Kutz.</td>
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<td><em>N. sabiniana</em> Patr.</td>
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<td><em>N. secura v. apiculata</em> Patr.</td>
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<td><em>N. subfasciata</em> Patr.</td>
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<td><em>N. tripunctata v. schizonemoides</em> (V. H.) Patr.</td>
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<td><em>N. viridula v. linearis</em> Hust.</td>
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<td><em>N. viridula v. rostellata</em> (Kutz.?) Cl.</td>
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<td><em>N. adapta</em> Hust.</td>
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<td>S. niagaeae Ehr.</td>
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<td>S. tenuis Hust.</td>
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<td>S. incisa Boyer</td>
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<td>S. ulna v. longissima (W.Sm.) Brun.</td>
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<td>Thalassiosira fluvialatus Hust.</td>
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2. *Stephanodiscus hantzschii* may contain *S. parvus* (Stoer.) Hakanns. specimens.
Appendix IV: A guide to the major species of diatoms identified from Irondequoit Bay

Two hundred fifty-nine species representing forty-one genera were identified from sediment samples from Irondequoit Bay. These species were identified using standard taxonomic keys. A record of these species was made by hand drawn diagrams as slides were examined. The diagrams of species representing the orders identified from the core are reproduced here. Only the most common species for these orders are shown. The drawing of many of these diagrams has been guided by diagrams found in referenced keys. The diagrams are accompanied by descriptions of major morphological features which aided me in the identification of species. This appendix should not be considered as a revision or substitute for any referenced source.
Order *Eupodiscales*
Family *Coscinodiscaceae*
Genus *Actinocyclus*

General Characteristics: In valve view, Cells are radially symmetrical. Large punctae or alveoli arranged in uniseriate rows. Rows are parallel to each other in facetted sections. A striated marginal area may or may not be discernable. Cells 20-60μm.
Order *Eupodiscales*
Family *Coscinodiscaceae*
Genus *Cyclotella*

General characteristics: Valves radially symmetrical, central area distinct in ornamentation from marginal area. Valve surface may be undulate in girdle view.

*Cyclotella meneghiniana*

Central area appears smooth or slightly undulate, mostly devoid of markings. Marginal area marked by radiating thickened costae with a distinctly "scalloped" marginal border.
Size generally 15-35 μ.

*Cyclotella bodanica*

Central area marked with radiating rows of punctae and a hyaline ringed area usually visible. One or two large punctae or process near center. Marginal zone marked with radiating striae, short thickened costae and large isolated punctae. Size 20-80 μ.
Order Eupodiscales
Family Coscinodiscaceae
Genus Stephanodiscus

General characteristics: Punctae in fascicles or bundles, biseriate or triseriate, no differentiation of ornamentation between marginal and central areas. Valve surface may be flat, domed or undulate.

Valve view

Punctae arranged in radiating rows, appear to be grouped in bundles of three. Punctae near the center of valve face become less organized and numerous. Large, robust spines are clearly evident and are generally placed in hyaline areas between rows of punctae. Rows of punctae extend from valve center to margin, no differentiation of central from marginal areas as in Cyclotella.

Stephanodiscus niagarae

Size of valves is quite variable, generally a large diatom, 50-150μ.
Valve surface is generally flat or only slightly undulate or dome shaped.

Semi-girdle view
Stephanodiscus alpinus

Valve view

Punctae appear in rows running continuous from center of valve to margin. Center area appears different but rows are continuous.

Central area may be convex or concave. Punctae arranged in biseriate fascicles at margins becoming more irregular and seriate near the center.

Short, stout spines are present but in many cases appear as indistinct "bumps" along the valve margin.

Size 15-35\(\mu\). May be confused with a small sized \(S\). niagarae.
Stephanodiscus hantzschii

Punctae very fine or nearly invisible, arranged in biseriate fascicles. Short, stout spines placed close to or at terminus of fascicles. Spines appear as "bumps". Spines may be only visible markings. In well defined specimens, a clear or shadowed ring may be visible near center of valve. Valve surface appears very flat, or slightly depressed giving impression of a "dinner plate". Size 8-20μ.
**Order Eupodiscales**  
**Family Coscinodiscaceae**  
**Genus Aulacoseira**

**General characteristics:** Cells appear as short cylinders. Colonies grow as long filaments. Cell surface ornamented with rows of punctae. Spines of various types may be visible. Cells are joined by pairs of connecting disks in most cases. Length to breadth ratio is diagnostic.

---

**Aulacoseira ambiguia**
- Long spines sometimes present. Helically arranged medium course punctae.  
- "V" shaped sulcus. Cell length to breadth ratio usually > 3.0

**Aulacoseira granulata**
- Short terminal spines, punctae fine, parallel to pervalvar axis.  
- Narrow sulcus, edges parallel to valve mantle.

**Aulacoseira granulata var. angustissima**  
**Aulacoseira distans**
Small spines may be visible near edge of valve face. Punctae numerous and fine, helically arranged. Sulcus "V" shaped.

*Aulacoseira italica*

Valve halves appear "nested". Larger valve half also appears thickened. No visible punctae.

*Aulacoseira varians*

No visible spines. Valve margin and valve surface nearly perpendicular. Punctae numerous and fine, parallel to valve margin. Sulcus "V" shaped.

*Aulacoseira islandica*

Spines barely visible. Punctae fine, arranged more or less parallel to valve margin. Intercalary bands present and overlapping.

*Aulacoseira binderanus*
**Order Fragilariales**  
**Family Fragilariaceae**  
**Genus Asterionella**

General characteristics: A common planktonic genera. Valves are elongate, symmetrical about apical axis. One apex larger than the other, usually capitate. Fine striae are indistinct in cleaned samples from lake Mendota in Wisconsin. Pseudoraphe is difficult to see. Living cells form distinctive, star shaped colonies with individual cells joined at large apices. Valves are asymmetrical about the transverse axis.
Order *Fragiliriales*

Family *Fragilariaceae*

Genus *Tabellaria*

General characteristics: Valves elongate, symmetrical about apical and transverse axes. Fine striae usually visible along all or part of valve surface. Valves often appear as empty septa, or chambers after cleaning. Apices distinctly capitate center is swollen.

*Tabellaria fenestrata*
**Order Fragrilariales**  
**Family Fragrilaríaceae**  
**Genus Diatoma**

General characteristics: Valves elongate to elliptical in valve view. Pseudoraphe indistinct. Surface marked by fine punctate striae and intermittent heavier costae. Valves in girdle view rectangular, but rarely seen in cleaned Irondequoit Bay samples. Living cells form "zig-zag" colonies similar in appearance to *Tabellaria* species.

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*Diatoma tenue var. elongatum*
Order *Fragilariales*
Family *Fragiliaceae*
Genus *Fragilaria*

General characteristics: Valves symmetrical about apical and transverse axes. No septa present. Pseudoraphe visible as narrow or broad space. Central area devoid of markings. Fine striae are composed of nearly invisible punctae. Colonies form filaments which are "ribbon like." Cleaned sediment samples did not contain filaments containing more than four or five cells. Valve views and girdle views are very similar.

*Fragilaria crotenensis*
Diagrams of additional common species from the sediments of Onondequoit Bay.

Order Fragilariales
Family Fragilariaceae
Genera Diatoma, Fragilaria

Diatoma vulgare
Fragilaria capucina
Fragilaria capucina var. mesolepta
Fragilaria construens
Fragilaria pinnata
Synedra acus

Additional common species found in the sediments of Onondaguit Bay.

Order Fragilariales
Family Fragilariaceae
Genus Synedra

Synedra rumpens

Synedra acus

Synedra capitata

Synedra delicatissima

Synedra ulna
Order Acnanthales
Family Acnantheaceae
Genera Acnanthes, Cocconeis, Rhoicosephenia

Characteristics of the order: Frustules have fully formed raphe on one valve and an axial space or pseudoraphe on the other. Valves elliptical to elongate in appearance.

Acanthanes lanceolata

Acanthanes minutissima

Cocconeis placentula
Raphe valve

Rhoicosephenia curvata
Girdle view
1-2 isolated stigmata on ventral side of raphe

1-5 isolated stigmata. Valve larger and more lunate than C. cymbiformis

Isolated stigmata may be present on dorsal side of raphe

Ventral edge of valve appears flat, or very slightly convex, not pronounced

Cymbella cymbiformis

Cymbella cistula

Order Naviculales
Family Cymbellaceae
Genera Cymbella, Amphora

General Characteristics: All genera have fully developed, two branched raphe on each valve. Raphe not part of keel structure or canal structure. Valve markings are bilaterally symmetrical about the transapical axis.
Amphora ovalis

Valve in girdle view appears as two Cymbella valves placed together.
General characteristics: Valves of the genus Gomphonema are generally known for being asymmetrical about the transapical axis. Other characteristics for the Order hold true.
Order **Naviculales**  
Family **Entomoneidaceae**  
Genera **Entomoneis**, **Plagiotropis**

General characteristics: Large complex valves. Rare in occurrence. Large bilobed structures with raphe in a "keel" or "wing".

**Plagiotropis lepidoptera**

*Note: Entire valve is visible in single focal plane*

**Entomoneis ornata**

*Note: Entire valve is not visible in single focal plane*
Order Naviculales
Family Naviculaceae
Genus Navicula

General characteristics: Valves are linear, lanceolate to elliptical in shape. The raphe is a simple structure, present on both valves and extends across the entire valve from a central point in the axial area. Striae are present and composed of various sized punctae. Orientation is transverse to raphe.

Navicula capitata

Navicula cryptocephala

Navicula cryptocephala
v. vaneta
Navicula reinhardtii

Heavy striae which appear to be large punctae and characteristic shape make this species easy to identify.

Navicula rhynchocephala

Thickened and raised central area with very fine processes which appear to be tiny punctae.
Navicula viridula

Rectangular central hyaline area

Striae sigmoid, convergent toward valve center

Navicula tripunctata

Circular central hyaline area

Striae are parallel and perpendicular to raphe
Order *Naviculales*
Family *Naviculaceae*
Genus *Mastogloia*

General characteristics: Valves elliptical to lanceolate with blunt or capitate ends. Striae are punctate, coarse to fine. Striae slightly radiate to parallel. Central area small. Distinctive feature in low focus is presence of "loculi" or marginal chambers.

*Mastogloia smithii*

*Mastogloia smithii* var. *lacustris*
Mastogloia grevillei

Valve ends more blunt
Intercalary band more uniform
Central "chamber shaped like "rolling pin".
Filiform raphe
Small, circular central area
Striae heavier, costae like.
Low focus
High focus

Mastogloia elliptica var. danseii

Central chamber "bar bell" shaped.
Intercalary band uniform width.
Filiform raphe
Central area irregular to "diamond" shaped.
Striae punctate
Low focus
High focus

Ends blunted most of all species.
Striae punctate, radiate at right angles to curve of valve margin.

Round central area

Striae punctate and finer. Striae run parallel to apical and transverse axes. They appear primarily longitudinal near valve margins at widest part of valve. Central area small and oval.

Gyrosigma accuminatum

Gyrosigma attenuatum

Order Naviculales
Family Naviculaceae
Genera Gyrosigma, Caloneis

General characteristics: Gyrosigma species have very characteristic "sigmoid" valves. Proximal raphe ends hooked in opposite directions or straight. Distal raphe ends straight. In Caloneis, a major identifying character is the presence of two longitudinal lines either side of the raphe. These lines delineate an inner chamber of irregular shape which is difficult to see in most cases.

Caloneis amphisbaena
Amphipleura pellucida

Frustulia rhomboides

Order *Naviculales*
Family *Naviculaceae*
Genera *Amphipleura*, *Frustulia*

General characteristics: The appearance of the raphe in a thick, heavily silified rib structure distinguishes these genera.

Siliceous rib widens into a raised nodule at each end of the valve. Raphe visible in these nodules.

Surface detail: Very finely punctate, often indistinguishable. Similar surface on *F. rhomboides*.
Diploneis oculata

Pinnularia stromatophora

Order Naviculales
Family Naviculaceae
Genera Diploneis, Pinnularia

General Characteristics: Diploneis has a strong apical siliceous ridge containing the raphe. The valve also displays costae or thickened striae parallel to the transverse axis. In Pinnularia, costae or striae are formed by chambers which join with the central vacuole of the cell. The edges of the chambers appear as a band or area of clear thickened cell wall. The raphe is usually a filamentous structure.
Order *Naviculales*
Family *Naviculaceae*
Genus *Neidium*

General Characteristics: Valves are linear, Lanceolate or elliptical. A great variation in morphology, some species have parallel margins. Central area oval to rectangular. Proximal raphe ends hooked in opposite directions, distal ends bifurcated. Striae are punctate and highly variable in arrangement. Longitudinal "rib lines" usually visible on valve surface.

![Diagram of Neidium affine](image1)

**Neidium affine**

*Neidium iridis*
Order *Naviculales*
Family *Naviculaceae*
Genera *Anomoneis, Stauroneis*

General characteristics: Valves usually lanceolate, transversely and longitudinally symmetrical. Central area is complex, joined with clear areas adjacent to the raphe, forming a "lyriform" or "H" shape. Stauroneis valves are distinguished by the "stauron" a clear area contiguous with central hyaline area, but extending to or nearly to the valve margins.

*Anomoneis sphaerophora*

Clear central and adjacent areas merge to form "lyriform" hyaline space

Capitate to rostrate ends

Straight raphe

Longitudinal, finely punctate striae

*Anomoneis vitrea*

10μ

10μ

*Stauroneis smithii*

Straight raphe

Recurved margin

Clear central area or "stauron" extends margin to margin
Epithemia argus

Order Epithemiales
Family Epithemiaceae
Genus Epithemia

General characteristics: Valves easily distinguished by shape. Symmetrical about transverse axis, asymmetrical about apical axis. Raphe is enclosed in a tubular canal. Surface is marked by a complex system of striae, alveoli and costae. Epithemia species often appear as septa only.

NOTE: Epithemia species often appear as septa. The valve appears as several, irregular connected chambers within the valve outline.
Order Epithemiales
  Family Epithemiacea
  Genera Denticula, Rhopalodia

General characteristics: Raphe like other members of this order, a tubular canal sunk into the valve surface. Denticula valves symmetrical about transverse and apical axes. Rhopalodia is asymmetrical about apical axis.

**Denticula tenuis**

**Rhopalodia gibba**
Order Eunotiales
Family Eunotiaceae
Genus Eunotia

General Characteristics: Valves curved or "lunate" generally, Raphe is rudimentary and seen only near the ends of the valve. The valve surface is marked by parallel striae which are indistinctly punctate. The striae may become radiate near the terminal nodules.
Order Surirellales
Family Surirellaceae
Genera Surirella, Cymatopleura

General characteristics: Both valves of the cells possess two "keel type" raphes along the valve margins. The raphe is a slit in a tubular canal which lies in a raised ridge or "keel" along the margin. The valve surface is marked by undulations and costae arranged in angular patterns.
Order Bacillariales
Family Bacillariaceae
Genus Nitzschia

General characteristics: *Nitzschia* valves have a single "keel" type raphe on each valve. In valve view the keel placement is variable but usually near the valve margin. In cross section the keels are placed diagonally opposed to each other. This separates this genus from *Hantzschia* in which the keels are placed on the same side in cross section.
Nitzschia hungarica

Note: Cross section of Hantzschia cell showing arrangement of "keel" and placement of raphe on both valves

Note: Cross section of Nitzschia cell showing arrangement of "keel" and placement of raphe on both valves

"keel" type raphe

Clear apical area running end to end

Fine, linear striae

"keel" type raphe

Clear unmarked valve surface

Nitzschia palea

10μ

10μ