

The recent history of Otsego Lake, New York, as determined from analysis of diatoms in a sediment core

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INTRODUCTION

Sediments, bearing the remains of siliceous diatom (Bacillariophyta) valves, accumulate in lakes. The valves do not readily decompose and they may remain in the sediment for centuries. With newer sediment covering the older deposits, diatom species that have particular environmental requirements may be used to chronologically indicate past lake conditions. Changes in biotic communities are a sensitive index to ecosystem condition. Diatom samples from sediment cores represent temporal continuum communities from all seasons, and can provide a means to see those impacts (Stoermer *et al.*, 1996). Diatom species complements have been correlated with nutrient trophic conditions by many including Osborne and Moss (1977), Fritz (1989), and Christie and Smol (1992). For the process of eutrophication, the diatom record can be the main indicator of change (<http://www.lochnessproject.org/lochnessproject/archiveroom/papershtml/sn93paper4.htm>). A Lake Trophic Status Index has been developed to relate diatom species to the trophic conditions of lakes. Generally, lakes with low nutrient concentrations are considered oligotrophic, and increasing enrichment produces mesotrophic then eutrophic lakes.

Otsego Lake, Central New York (42°40'N-70°00'W, Fig. 1) is in a shale tongue valley, over-deepened by glacial erosion (Sales *et al.*, 1975). The watershed includes 44% agricultural land, 36 % hardwood forest, and 14.5% brushland (Harman, *et al.*, 1997). There are many creeks that empty into this lake, which is located at the head of the Susquehanna River. The Otsego County towns of Otsego, Middlefield, Springfield surround the lake. Portions of the watershed to the north are within Herkimer County.

The Iroquois people used the nearby land as a hunting ground; deer hunters burned parts of the forest to clear underbrush. Traders plied the waters. Then in 1768, Susannah and Augustine Prevost Jr. settled at the head of the lake. They cleared 18 acres, and built a cluster of log buildings, including a sawmill. This and other settlements were soon abandoned (Taylor, 1996). This area's most famous settler and founder of Cooperstown, William Cooper, arrived in 1785. During the 1800s, the watershed and lake saw the growth of agriculture and steamboat transportation. Some boats carried up to 300 passengers (Harman *et al.*, 1980).

Otsego Lake is in the General Appalachian Cloudiness Belt, an area of long, cold winters, receiving about 40% of possible sunshine in the winter (Harman *et al.*, 1997). Its narrow, steep morphology allows a limited phototrophic zone. Nutrient runoff originates through agriculture in the rich limestone-derived soils. The lake has high

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nitrogen: phosphorus ratio (40:1), so P is a determinant of lake productivity (Harman *et al.*, 1980). With an area of 1,711 hectares, and a maximum depth of 50.5 meters, Otsego Lake has been studied intensively since 1968 through the SUNY College at Oneonta Biological Field Station. This study was undertaken to examine the history of lake conditions as revealed by the diatom complements in a sediment core.

METHODS

Six cores were taken with a multiple gravity corer from the SUNY Oneonta Biological Field Station barge in the deepest part of the lake (50.5 meters, Fig. 1) on October 8, 2002. Cores were frozen, and two were split. A 26 cm core (Core II) was cut into 1 cm sections. A small amount of sediment from selected samples was cleaned with 30% hydrogen peroxide and coverslips were made using Battarbee chambers (Battarbee, 1973). The coverslips were then mounted in Pleurax. Examination of several samples from Core II revealed that diatoms appeared too sparse to be meaningfully enumerated in the bottom half of that core. Given this, and the lake's presumably low sedimentation

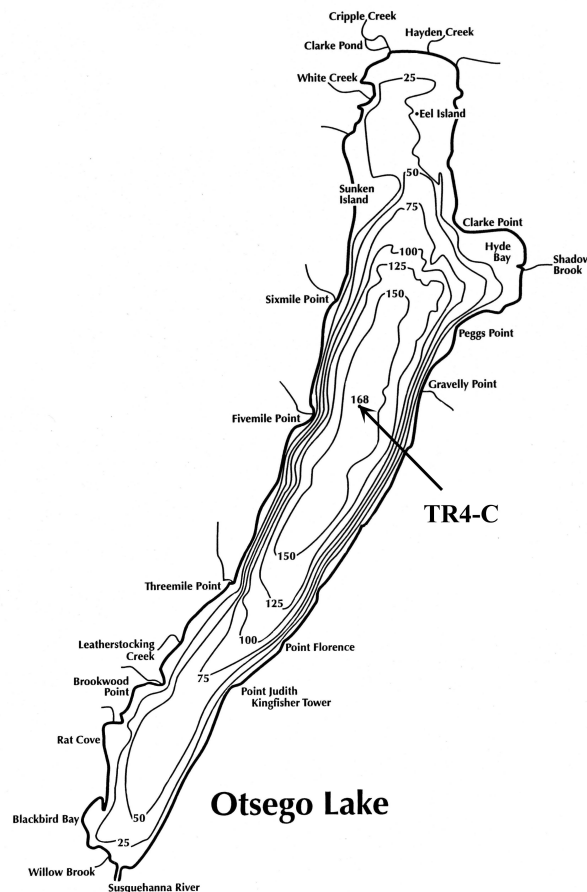


Figure 1. Otsego Lake, NY. Core I was taken at TR4-C. (Map from Harman, personal communication)

rate, a 16 cm core (Core I) was sectioned at approximately 0.5 cm intervals and used for examination. About three hundred valves from each sample were enumerated with a Bausch and Lomb Balplan microscope at 1000x using phase contrast. They were identified according to Patrick and Reimer (1964), Dodd (1987), Huber-Pestalozzi, (1942). The Lake Trophic Status Index (LTSI) was calculated using the formula of Yang and Dickman (1993): $LTSI = 2.643 - 7.575 \log [(O\% + OM\% + M\%)/(E\% + ME\% + M\%)]$ where O = oligotrophic, OM = oligomesotrophic, M = mesotrophic, ME = mesoeutrophic and E = eutrophic. Oligotrophic, oligomesotrophic, mesotrophic, mesoeutrophic and eutrophic refer to diatoms that respectively indicate conditions of progressively higher nutrient enrichment.

RESULTS AND DISCUSSION

As the sediments in this core were not lead dated, other means had to be used to determine their estimated age. A previous study had located the approximate level (0.3 m) where slag and grains such as sandstone and siltstone began to appear in a core (Sales, *et al.*, 1975 and Breuninger, personal communication). The slag, from steamboats and the railroad, as well as the sand and siltstone fragments, were deposited through human activity. The first Otsego Lake steamboat sailed in 1858 and the first train ran in 1869. Although the core mentioned above was taken in the southern end of the lake, rather than the middle as was the present core, Marchetto and Musazzi (2001) determined that cores taken in various areas of a large deep lake should be similar. Considering the time elapsed since the beginning of the steamboat period, and when cores were removed by Sales, a sedimentation rate for the past 144 years was calculated as 0.26 cm per year. This seems a reasonable estimate, considering events that have historically occurred in the watershed. This is approximately the same sedimentation rate as Hemlock Lake, determined for a study done by Chaisson (2002, unpublished data). Hemlock Lake is an oligotrophic Western New York Finger Lake. Similar to Otsego Lake, it is narrow with steep sides and it is also used as a water supply; it was formerly surrounded with cottages. The year mentioned when referring to a given sample in this report is the earliest year calculated for that sample based on the slag and grains that would have begun to appear in the sediment in 1858. It is further noted that this is not laminated sediment, so years are approximate, not exact.

Diatoms were sparse at the very bottom of Core I. Many reasons such as dissolution, lack of production and burial in excessive sediment have been given for obtaining sediment with a low concentration of diatoms (Fritz *et al.*, 1993). It is possible that a deeper core would contain a higher concentration of diatoms in lower samples (Breuninger, personal communication).

The lowest level of sediment analyzed is from about 1950. There were at least 147 buildings around Otsego Lake by then (Harman *et al.*, 1980). The hops industry that had thrived in the area in the previous century was gone, but agriculture was still important. The species *Aulacosiera subarctica*, which indicates oligomesotrophic conditions, has an average relative abundance of 38.2% (Fig 2) in samples from sediment

deposited between 1950 and 1958. It was found, at least to some degree, in samples throughout this core, which is not surprising considering the cold climate. *Aulacosiera subarctica* is able to bloom under winter ice cover with little light, and survive in a dormant stage for more than two centuries (Kienel, personal communication). In the Great Lakes, it attains maximum abundance during winter circulation (Stoermer *et al.*, 1996). *Aulacosiera subarctica* has been found in lakes with even extremely low levels of nutrients such as phosphorus (<http://www.lochnessproject.org/lochnessproject.org/lochnessproject/archiveroom/papershtml/sn93paper4.htm>), yet it can tolerate enrichment (Stoermer *et al.*, 1996). *Cyclotella comensis*, an oligotrophic indicator, showed 17.0% (Fig. 2) average relative abundance during this period. It would appear that this was a time of low nutrient enrichment in Otsego Lake. There are, however, mesoeutrophic and eutrophic indicator species in addition to oligotrophic and oligomesotrophic indicators (Fig. 6). The nutrients for the former come from agricultural runoff through Cripple Creek, Hayden Creek and Shadow Brook; septic systems are potential sources of enrichment as well (Harman *et al.*, 1980).

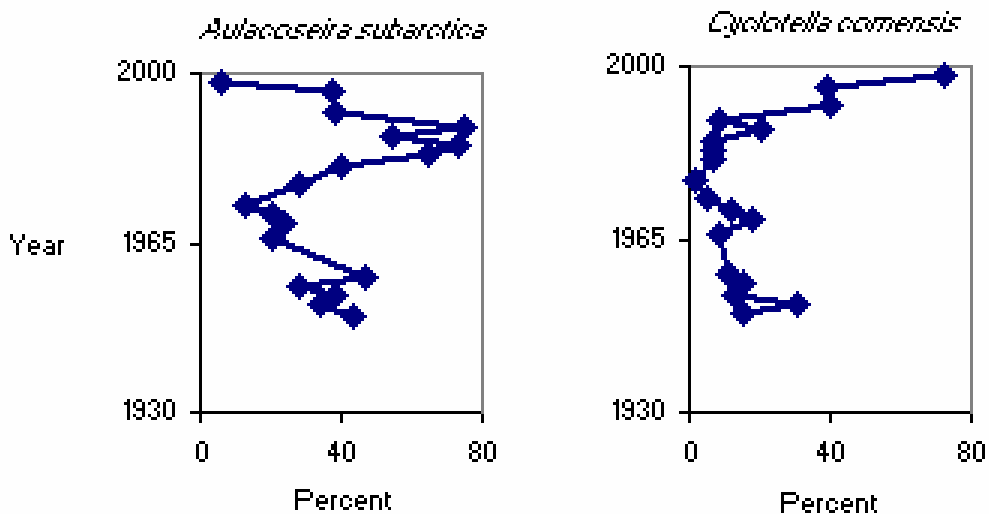


Figure 2. Percents of *Aulacoseira subarctica* and *Cyclotella comensis*.

The average relative abundance of *A. subarctica* (19.3%) and *C. comensis* (11.0%) declined from 1966 until 1973, while other species increased in relative abundance. Mesotrophic *Punctastriata pinnata* reached a peak of 7.7% (Fig. 3) in 1973. Between 1966 and 1973 oligomesotrophic indicator *Achnanthes minutissima* had an average relative abundance of 4.2% (Fig. 3), mesoeutrophic *Stephanodiscus alpinus* 5.6% (Fig. 3), and *Stephanodiscus parvus* 4.4% (Fig. 3). *Stephanodiscus alpinus* tolerates eutrophic conditions by varying its morphology, and it succeeds well at very low temperatures (Stoermer *et al.*, 1996). Fritz *et al.* (1993) indicate that an increase in *S. parvus* suggests an increase in phosphorus. *Stephanodiscus parvus* is a eutrophic indicator (Blais *et al.*, 2000). *Cyclotella radiosa* reached an average abundance of 8.6% (Fig. 4); *C. distinguenda*, 4.0% (Fig. 4); *C. michiganiana*, 8.4% (Fig. 4); and *C. stelligera*

v. tenuissima, 3.0 % (Fig. 4) between 1966 and 1973. Studying samples of 42 lakes, Fritz *et al.* (1993) found other *Cyclotella* species characteristic of higher nutrient concentrations than *C. comensis*. The increase in those species may suggest a slight increase in available nutrients, although the factors controlling dominance in *Cyclotella* are not known

The Glimmerglass State Park opened in the late 1960's, and the effluent from its sand-filter, wastewater treatment system entered the lake through Shadow Brook. With concern for the lake, sub-surface disposal was implemented in 1977 (Harman *et al.*, 1980). Area population increased from visitors to the park, and the number of buildings and residents, around the lake increased to 273 by 1969 (Harman, *et al.*, 1997). These factors likely contributed to increased nutrient levels in the lake. The diatom species complements changed greatly between 1958 and 1973.

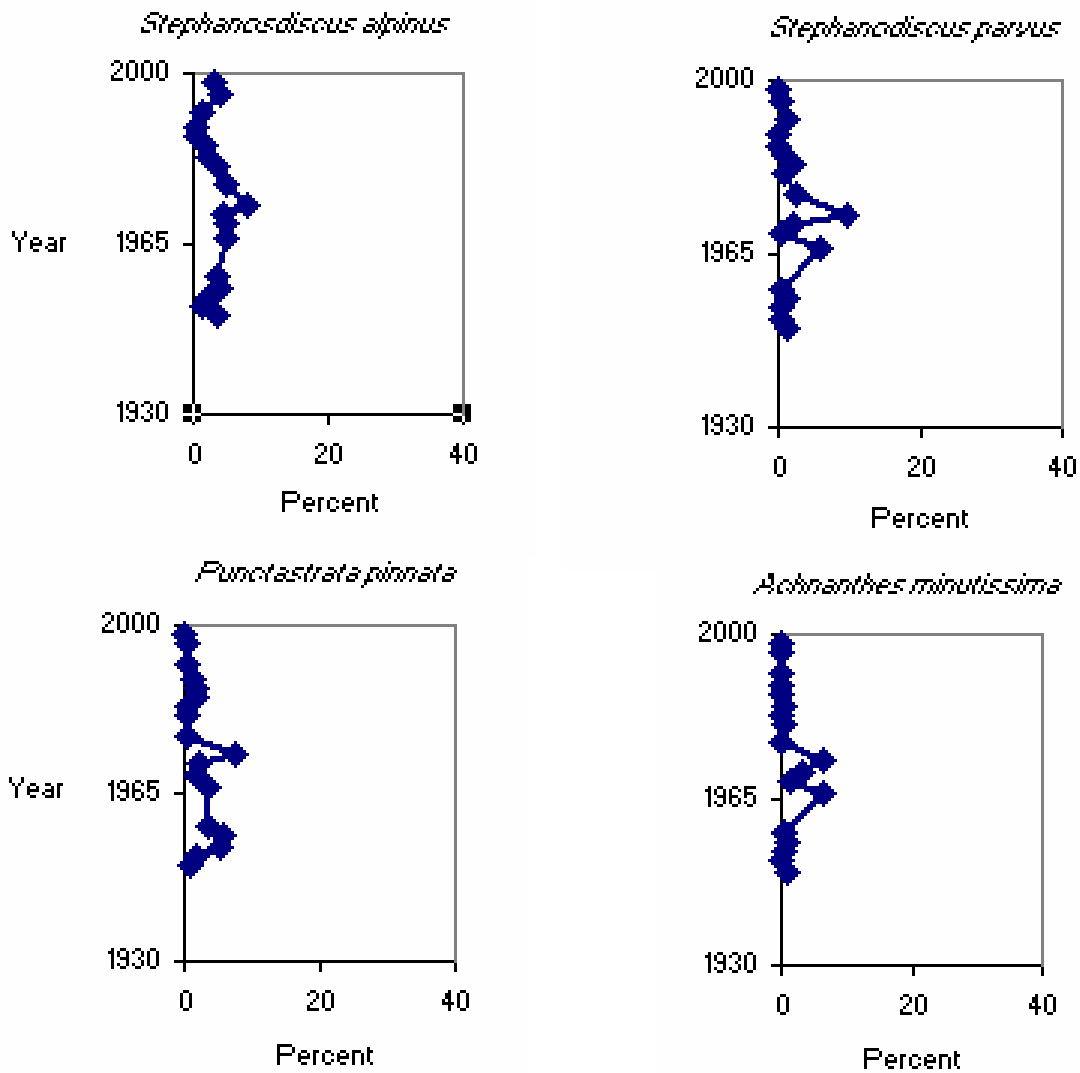


Figure 3. Percents of *Punctastrata pinnata*, *Achnanthes minutissima*, *Stephanodiscus alpinus* and *Stephanodiscus parvus*.

Change persisted after 1973 until 1981. *Cyclotella radiosa* continued to increase and averaged 18.4% (Fig. 4) relative abundance. Peaks of relative abundance of mesoeutrophic *Tabellaria fenestrata* (10.1%) (Fig. 5) and mesotrophic *Fragilaria crotonensis* (12.9%) (Fig. 5) appeared by 1977.

Fritz *et al.* (1993) found shallower lakes to be productive and dominated by, among others, *Synedra* spp. and *F. crotonensis*. There are many small pieces of broken *Synedra* spp. evident in the slides made from these 1977 and 1981 samples. *Synedra* tend to be very long and fragile; their small pieces cannot be included in species enumeration. The waste from the state park was probably still impacting the lake during

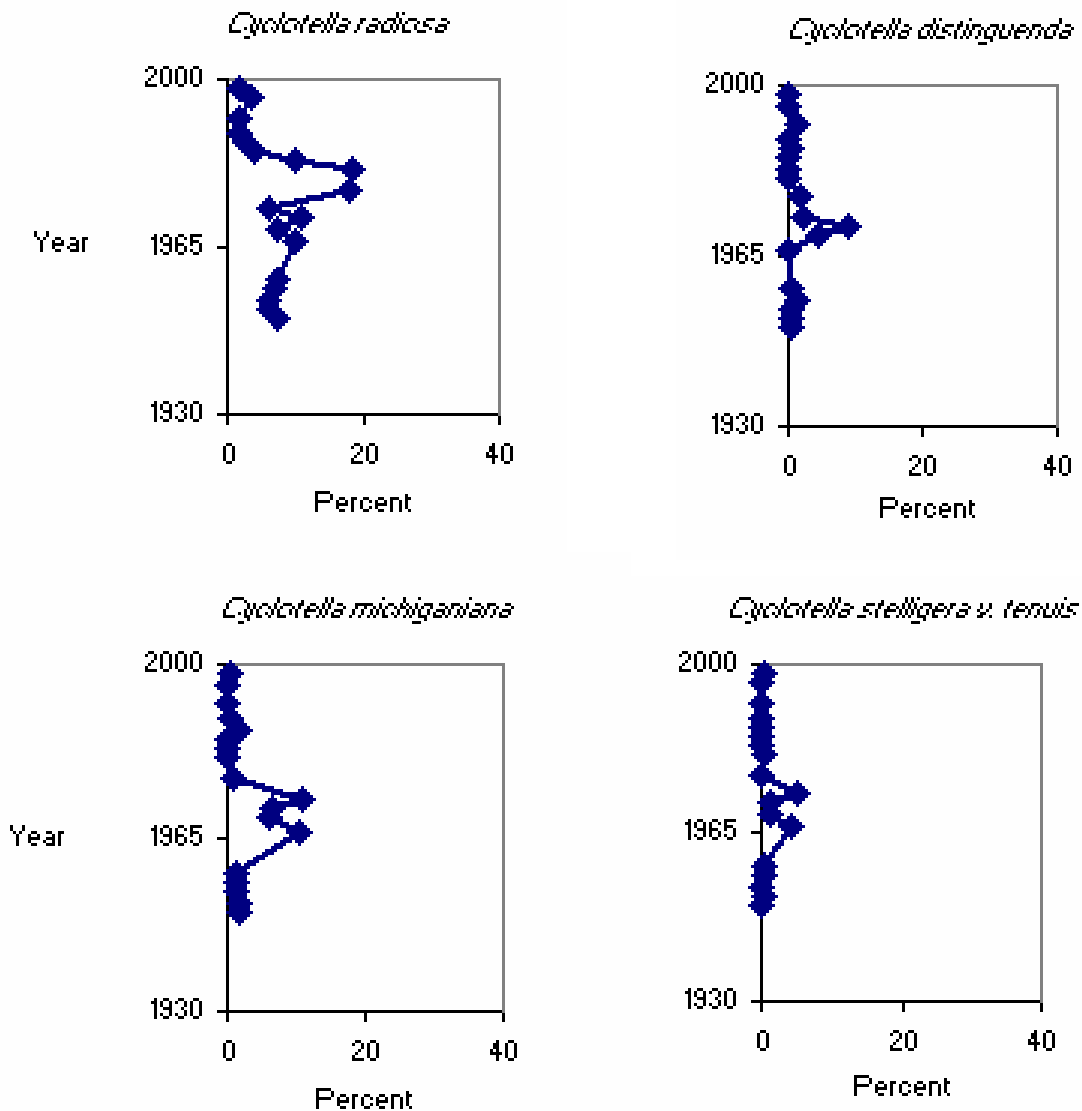


Figure 4. Percentages of *Cyclotella* species.

this period, but the new filtration system was established in 1977. In these samples, oligotrophic and oligomesotrophic indicators increased from a low of 35.7% in 1973 to 66.1% (Fig. 6) relative abundance in 1981. There is a decrease in eutrophic indicators from 10.4% in 1973 to 1.4 % (Fig. 6) relative abundance in 1981. It would appear that the lake was recovering from the excess enrichment of the late 1960s and early 1970s. Between studies done in the early 1970s and 1988 there were significant reductions in phosphorus concentrations in the lake. In addition to the needed

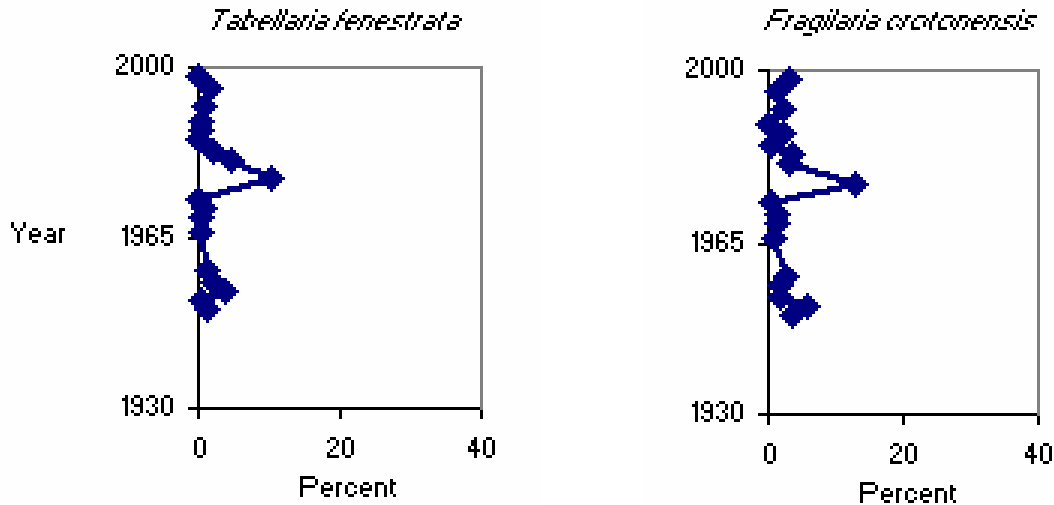


Figure 5. . Percentages of *Tabellaria fenestrata* and *Fragilaria crotonensis*.

improvements to the sewage disposal system at the Glimmerglass State Park, a ban on phosphate-containing detergents was enacted (Harman *et al.*, 1997). In a similar study, Garibaldi *et al.*, (1997) found that lower sewage inputs and reduced phosphorus in detergents (by Italian law in the early 1990s) were associated with improved conditions in Lake Endine. *Aulacosiera subarctica* began to increase in relative abundance after 1973 and in 1989 reached a relative abundance of 74.5% (Fig. 2). Again, it would appear that during the 1980s the conditions in Otsego Lake were improving after the enrichment of the 1970s.

It should be noted that the 1960s and 1970s were not a period of short average ice cover that might have contributed to the decline in percent of *A. subarctica* during those decades. The average number of ice cover days was 94.6 from 1960-1979 and 82.6 during the 1950s and from 1980-1995 (Diaz, 1978 and Harman, 1997).

From 1992 to 1996, the average relative abundance of *A. subarctica* decreased to 37.7% (Fig. 2), while *C. comensis* accounted for 39.5% (Fig. 2) of the valves. By the top of the core the *C. comensis* attained 72.0% relative abundance. This species has typically been considered an oligotrophic indicator, with low nutrient requirements. This is also a morphologically variable species (Fritz *et al.*, 1993 and Hausmann and Lotter, 2001). Stoermer (personal communication) feels that its taxonomy has not been clarified, but

generally the *Cyclotella comensis* group is found under lower nutrient concentrations than other *Cyclotella* (Fritz *et al.*, 1993). From 1973 to 1994, nitrite and nitrate levels stayed relatively constant (0.63 mg/l in 1994) in Otsego Lake. Between 1988 and 1994 however, total phosphorus concentration doubled to 10 $\mu\text{g/l}$. This was associated with the subdivision of farms and forests, especially in the areas drained by Cripple Creek, Hayden Creek and Shadow Brook. Old septic systems around the lake also contributed phosphorus to the lake (Harman, *et al.*, 1997).

Why would the presence of an oligotrophic indicator expand with increased phosphorus loading? It is interesting that *C. comensis* has increased in oligotrophic lakes worldwide since the 1970s (Stoermer, personal communication). The reason is not completely clear. *C. comensis* prefers a high nitrogen to phosphorus ratio, which is found in Otsego Lake. Many other reasons have been put forth for the widespread increase in *C. comensis*. Increased atmospheric nitrate loading, the effects of a micronutrient, the seasonality of nutrient inputs, other limnological variables not considered in data sets (Fritz, *et al.*, 1993), even increased spring temperatures (Sorvari, 2001) have been postulated. The action of *Dreissena polymorpha* (Stoermer *et al.*, 1996) has been considered as a reason for the wide upsurge in *C. comensis*, but zebra mussels have not been reported in Otsego Lake.

To quantify the trophic states of lakes, Yang and Dickman (1993) analyzed phosphorus, chlorophyll-a and Secchi disk depth of 30 Canadian lakes. They related this information to the diatom complements found in the lakes and developed a Lake Trophic Status Index or LTSI. It is not an exact index, but one means of classifying lakes.

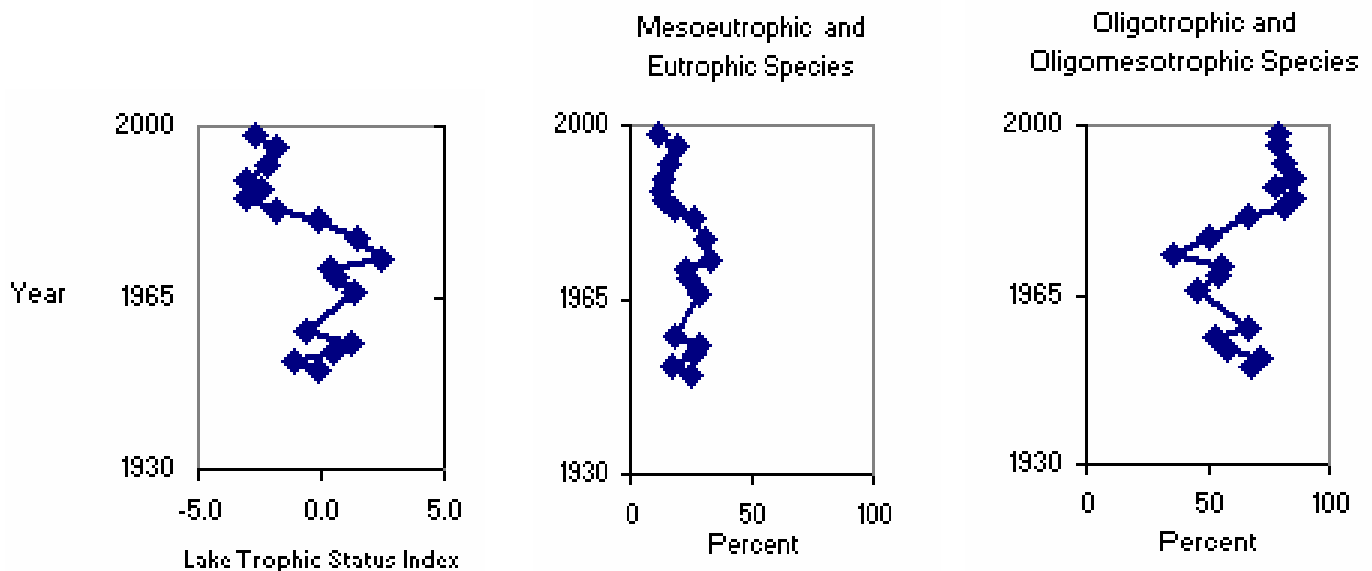


Figure 6. Changes in Lake Trophic Status Index (LTSI) over time in Otsego Lake (a) and changes in percent of mesotrophic and eutrophic species indicators (b) and oligomesotrophic species indicators (c).

Throughout most of the Otsego Lake core, the Lake Trophic Status Index values (-3.0 to 2.5; Fig 6) suggest oligotrophic conditions in the lake, except the 2.5 value for in 1973 indicates oligomesotrophic conditions.

In a recent examination of diatoms from a sediment core from Hemlock Lake, a Western New York Finger Lake, the present author found the continuous presence of *A. subarctica* since 1873, as well as the striking increase of *C. comensis* toward the top of the core. Hemlock Lake, with a morphology similar to Otsego Lake, is also currently considered oligotrophic, according to the LTSI. The LTSI indicates that Hemlock Lake was mesotrophic during the 1950s.

In summary, between the 1950 and 2002, Otsego Lake was usually in an oligotrophic condition according to the Lake Trophic Status Index. There are species present that indicate some enrichment to the lake system, likely from sewage and agricultural runoff between the mid-1960s and the late 1970s. The decline of *A. subarctica* and the proliferation of many other species showed during that period illustrates true changes.

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