LIMNOLOGY LAB

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An Assessment of Relative Trophic Status of Four Westchester County Lakes

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Lakes: Calder, Waccabuc, Bowman I, and Bowman II

Before attempting to assess the trophic status of these lakes, a review of the evolution of the eutrophication concept seems in order (and, indeed, is called for).

The use of the word "eutrophic" and its opposite, "oligotrophic" originated with Weber (1907: summarized in Hutchinson 1973) who used the words to describe nutrient conditions of vegetation in German peat bogs. Initially, the bog vegetation required high concentrations of nutrients which he called eutraphent (rich in nutrients). As the bog built up in elevation, the vegetation was more leached of nutrients and was composed of plants whose nutrient requirements were much lower, - oligotrophent (poor in nutrients).

Naumann (1919) (see Hutchinson 1973,) used Weber's terms in his writings to describe water types and different associations of phytoplankton, so that oligotrophic, mesotrophic, or eutrophic waters contained increasing concentrations of nutrients. He did not apparently measure these concentrations, but drew his conclusions from just looking at the transparency and color of the lakes.

Other limnologists then began to use, and sometimes confuse, this basic scheme. Thienemann, (1918) (Hutchinson 1973) whose work was done mostly on very deep temperate lakes, was struck by the differences in the fauna and the oxygen concentration in the bottom waters of deep and of shallow lakes. He regarded the deeper lakes as oligotrophic and the shallower ones as eutrophic. Since the latter had hypolimnions which tended to run out of oxygen, and consequently were inhabited by numerous but relatively few species of bottom fauna that could tolerate the low oxygen levels.

By applying the concepts of oligotrophy and eutrophy to lakes rather than to waters the trophic implications could be lost: for example, when an oligotrophic lake becomes eutrophic by filling up with sediments. Lundbeck (1934) (see Hutchinson) tried to distinguish a very deep lake which contained eutrophic or mesotrophic water, but which had much oxygen in the hypolimnion as "secondarily or morphometrically oligotrophic."

As the concept continued to evolve some investigators emphasized the importance of the ratio of water volume to sediment surface in a shallow more mature basin. The amount of nutrient material which can diffuse from mud to water is obviously greater in shallow than in deep lakes. (Strom)—see Hutchinson) Still others focused on the effects of the drainage basin, and the amounts of nitrogen and phosphorous entering the lake in silts, forest litter and their decomposition products.

Rodhe (1969) characterized lake trophic conditions according to the degree to which the organic matter was autotrophic or allotrophic. Birge and Juday made the same distinction in their work on Wisconsin lakes with regard to the origin of dissolved organic matter: autotrophic lakes - dependent on internal sources, and a1lotropic lakes which receive a major part of their organic solutes from external sources. (Rodhe 1969)

Jarnefelt and G.E. Likens (see Hutchinson and Rodhe) in their work expanded Rodhe's scheme by discussing productivity in terms of allocthonous inputs of nutrients and organic matter and autocthonous inputs. Likens said that eutrophication was nutrient or organic matter enrichment, or both, that results in high biological productivity and a decrease in volume in the lake ecosystem (i.e. filling in of the basin). (Klemer - class notes 9/27/76) This definition does not distinguish between the different kinds of productivity, - for example, green vs. blue-green algae, or between the different kinds of fish species, that characterize oligotrophic and eutrophic lakes.

It was left for limnologists such as Hutchinson to emphasize the fact that eutrophication involves more than nutrient enrichment. It involves the particular kinds of algae that are present, - blue-greens in eutrophic lakes which limit or eliminate other fauna. Hutchinson also observed (1973) that so-called natural eutrophication (the aging process from oligotrophic to eutrophic status) was probably not "natural" but man-induced. There had been long steady states, for example, in both Lago di Monterosi and Linsley Pond as shown by their sediments until human interference triggered a change towards eutrophication. In addition, he states that outside the glaciated humid temperate regions, there seems to be no inevitable change from oligotrophy to eutrophy. (19:3)

Refinement of the eutrophication concept will undoubtedly continue as research accelerates on what is a growing world-wide problem, viz. the rapid eutrophication of lakes. But in this paper the concept generally following Hutchinson and Klemer.

This assessment of relative trophic status of the four lakes is based on data collected during the fall of 1976. The data includes: Secchi readings, measurements of depth, temperature, alkalinity, conductivity, pH, dissolved oxygen concentrations, chlorophyll determination, and a (limited) survey of dominant algal species found in the lakes.

Methods

Measurements and water samples were taken on successive Saturdays between Sept. 25, 1976 and Oct. 23, 1976. Only Lake Waccabuc was revisited: on Oct. 9 end 23. Lake depth was determined by a marked line, and measurements with a temperature and oxygen meter, and with a Secchi disc were taken by boat in the middle of the lake. Water samples were collected with a Van Dorn bottle and Lund sampler. Plankton net samples were also collected.

Dissolved oxygen values were determined. in the lab by means of the Winkler Method. These values appear to be considerably more accurate than the values obtained by the Yellow Spring Oxygen Meter (Analyzer), therefore the latter results will not be presented. Conductivity, pH, and alkalinity values were determined potentiametrically in the lab from the water samples.

Chlorophyll determinations to obtain an indication of algal abundance were made following the procedure used by Lorenzen (1967) (see Vollenweider 1975).

RESULTS

The lake data is presented comparatively in graph and table form.

Table 1. Transparency and Lake Depths (in meters)
(Secchi disc readings (m.)

Lake	Depth (m.)	Transparency (Secchi reading)
Calder	5.13	2.5-3.7
Waccabuc	12.0	1.75
Bowman I	1.5	0.75
Bowman II	9.0	1.0

Table 2. pH (range values are surface to depth)

Lake	pH
Calder	7.2 – 6.9
Waccabuc	6.9 – 6.2 (Oct. 9) 6.4 – 7.0 (Oct. 23)
Bowman I	6.6
Bowman II	7.7 – 6.8

Table 3. Chlorophyll a and Pheopigment Values

Lake	Depth of Sample	Chlorophyll (ug/L.)	Pheopigment (ug/L.)	Ratio Chl vs. Pheo
Calder (10/2)	Unknown Unknown	3.921 0.521	1.194 2.477	3.28 0.21
Waccabuc (10/23)	1.0 m. Lund Sampler	5.747 2.495	0.053 2.370	108.43 1.05
Bowman I (10/9)	0.0 m.	3.564	1.426	2.50
Bowman II (10/9)	0.0 m.	2.851	0.232	12.29

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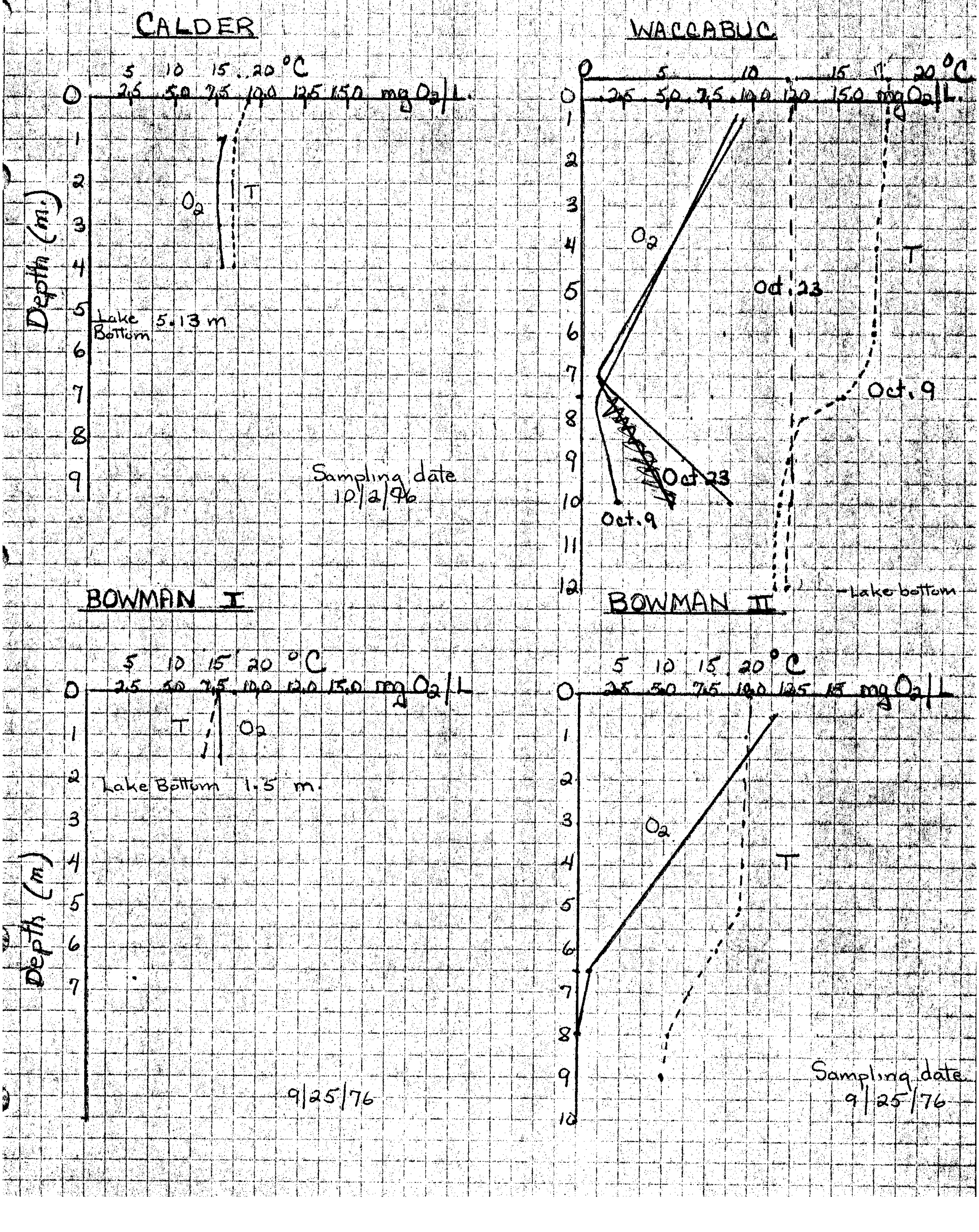
Table 4. Algal Presence and Dominance
(X indicates presence ; D - dominant species; SD - sub-dominant species;
* - blue-green algae)

Species	Calder	Waccabuc	Bowman I
Anabaena *	(SD) X	X (D)	
Oscillatoria *		X (D)	
Coelosphaerium *	X (D)	X	X (D)
Fragillaria		X	
Melosira	X		
Ceratium	X	X	
Staurastrum		X	
Diatoma			X
Microcystis *		X	
Aphanizomenon *		X	
Navicula		X	

(Data not available for Bowman II and perhaps incomplete for Bowman I)

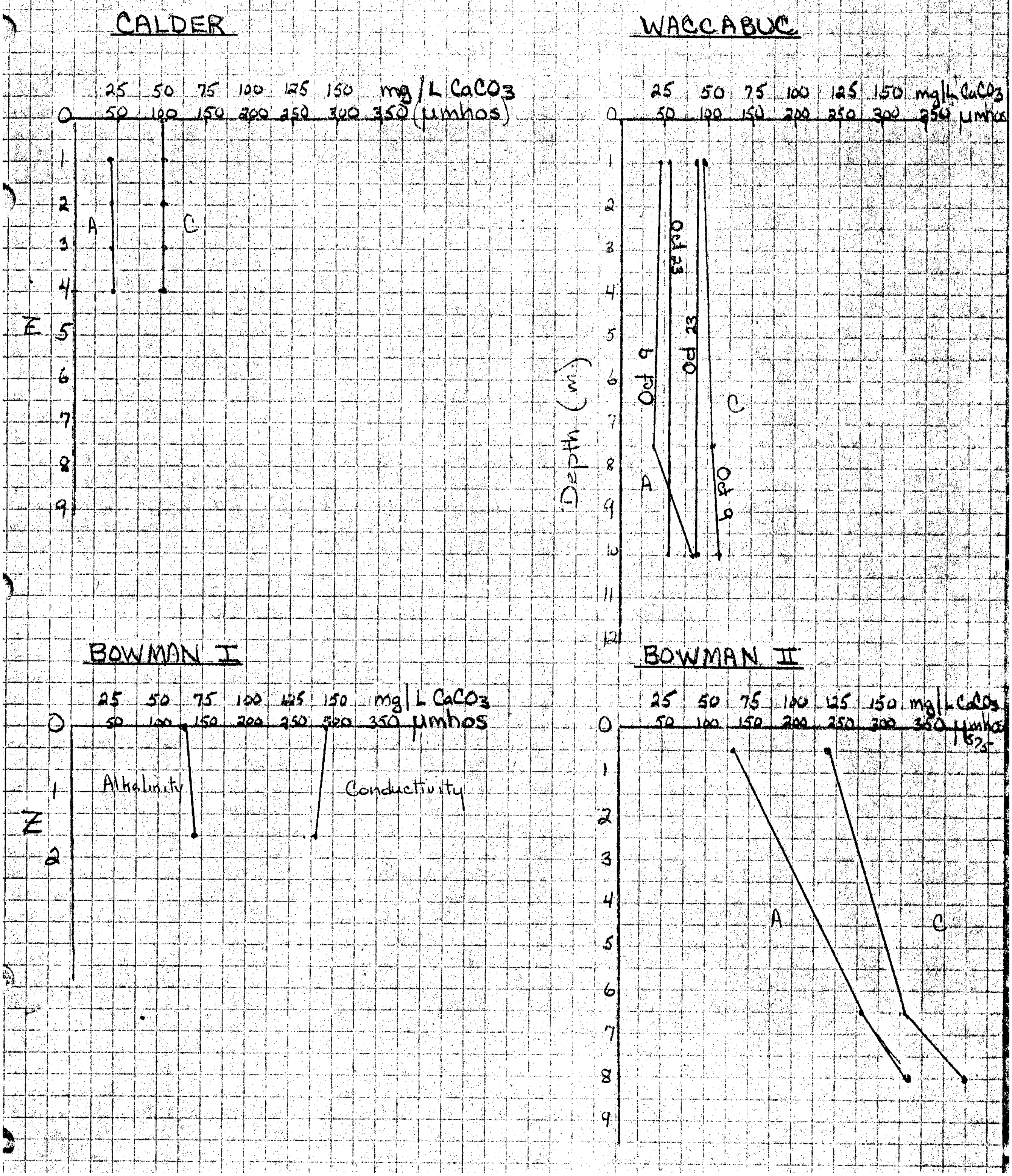
Graph 1

TEMPERATURE AND OXYGEN PROFILES OF FOUR LAKES



(A ——) ALKALINITY AND CONDUCTIVITY (µmhos) (—— C)

Graph 2 VALUES FOR THE FOUR LAKES



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Discussion

Calder Lake

This small lake appears subject to the least human impact as there is no observable development except the Fordham Limnological Laboratory, and one nearby house. The lake was isothermal (or nearly so) on the sampling date (10/2) with an orthograde oxygen curve. Its Secchi reading was the highest of the four lakes, though varying readings were obtained by different readers of 2.5 - 3.7 m. Alkalinity values, also the lowest of the four lakes, (at 21.87 - 22.50 mg/L $CaCO_3$) coupled with fairly low conductivity (103 umhos) suggest that this lake might be the least productive of the four.

However, the chlorophyll a value of 3.9 ug/L does not reinforce a picture of low productivity since it is the second highest value obtained in the lakes. An apparently inexplicable ratio of 0.21 for the chlorophyll a/ pheopigment values in the second Calder sample can be explained if this sample was taken from the lake bottom. (Neither sample had a depth marking unfortunately.) A bottom sample could account for this high level of degradation, since it would contain much "plankton rain" of dead cells.

The algal dominance picture is also suggestive of a productive (eutrophic) lake since Coelosphaerium and Anabaena (both blue-green algae) were the dominant species found in the sample.

Waccabuc

This larger, deeper lake has 300 homes around its shoreline all of which are served by septic tanks. "Significant amounts of nutrients undoubtedly enter the lake from these sources and from lawn fertilization (Arlo Fast, et. al. 1975). Because of the lake's progress towards eutrophication, the residents had Union Carbide install a hypolimnetic aeration system in 1973, which has apparently increased the hypolimnetic oxygen while preserving thermal stratification (Fast, at. al. 1975). The presence of the aerator probably accounts for the increase in oxygen noted at the 10 m. level on both visits to the lake.

Between the first and second sampling dates thermal stratification disappeared as the lake turned over. The dissolved oxygen in the metalimnion during stratification (on 10/9) in the metalimnion was very low (1.14 mg/L) indicating the lake's battle with eutrophying factors and the increase below this level in the hypolimnion to 3.56 mg/L at 10 meters can be attributed, as noted, to the aerator. After mixing the D. O. values at the surface and the 10 meter mark were found to be nearly equal (9.4- and p.1)'. However', a low of 1.14 was still (apparently) recorded at the seven meter level which is very difficult to explain. If the metalimnion were densely inhabited by blue-green algae taking up CO_2, (and alkalinity did do- crease somewhat at that level during stratification),(see Graph 2) they would produce oxygen during the day as well as using it up in respiration. The low reading at this level could indicate some source of debris or influx of organic matter creating an oxygen demand (and the heterograde curve), but is still lower than expected at this level. (It might also indicate the bottom of the photic zone and lower limit of photosynthesis – so that there is not a positive increase in O_2.)

The Secchi reading was somewhat lower than Calder indicating increased algal biomass (and the chlorophyll a value was higher) and/or increased turbidity. Alkalinity values were only slightly higher than those in Calder, though the hypolimnetic value (39.60 mg/L $CaCO_3$) before turnover was noticeably higher. Conductivity values are comparable to those found in Calder and they showed a decrease upon mixing which might indicated some degree of settling out of dissolved solids.

The chlorophyll a value was the highest of the four lakes (5.747 ug/L) at the one meter level and the ratio to pheopigments was unbelievably high - 108.43. It is difficult to hypothesize a cause for such a lack of pigment degradation, but the sample was taken on 10/23, after turnover and many of the dead cells may have settled out. (But that many?) (A general lack of close correlation of the chlorophyll a values with the other indicators of productivity is rather perplexing and may simply indicate faulty lab technique.)

Bowman I

Bowman (I) is the upper lake of two adjoining lakes, one above, the other below a dam. It is small and shallow (1.5 in.) formed by the water of Blind Brook impounded behind the Rye City dam. This lake showed no appreciable temperature or oxygen stratification though the sampling date was the earliest. (9/25) The conductivity and alkalinity readings which were quite high did not show any significant increase with depth. It would appear that the shallow depth and active inflow and outflow at the dam cause the lake to turn over easily. On this same dates Bowman II (which is considerably deeper) was thermally stratified. The dissolved oxygen content was reasonably high throughout (7.8 mg/L at 0 m.) perhaps due to the ease of mixing by the wind and greater interaction with the atmosphere. It also had the lowest Secchi reading (.75 m.) which is probably due to turbidity from mixing as well as productivity.

Conductivity and alkalinity in both Bowman I and II were much higher than that found in Calder and Waccabuc and were quite comparable, (289 to 240 umhos at 0 m. and 63.9 to 66.6 mg/L $CaCO_3$ at 0 m.) This drainage basin is under increasing human impact. Bowman I has no human habitation around its immediate shoreline but is situated between a nearby road and highway.

The chlorophyll a. value was not as high as might be expected from the high conductivity and alkalinty readings, however it was obtained from a surface sample and the value may have been higher at a slightly lower depth due to inhibition by light intensity to algal growth at the surface. The ratio of chloro. a/ pheopigments - 2.50 is still quite high apparently indicating little pigment degradation and phytoplankton morbidity. Again, settling with mixing may be a cause.

Bowman II

The lake below the dam, an old gravel pit in part, is surrounded by very intensive human development factors, - a shopping center, location between the two roads mentioned before, and use by some local inhabitants as a "sink". It was still stratified on 9/25 with a measurable thermocline at approximately six meters extending to eight meters. It also showed complete oxygen depletion by a depth of eight meters reflected in. the clinograde oxygen profile (Graph 1). The smell of (H_2S) hydrogen sulfide was detected in the hypolimnetic water samples indicating reducing conditions at the bottom of the lake.

This may also be an indication that the lake is rich in sulfates since "as a rule only those eutrophic lakes that are also rich in sulphates have large amounts of hydrogen sulphide in the hypolimnion." (Ruttner pg. 92)

The highest conductivity and alkalinity values of the four lakes were found in the hypolimnion of Bowman II, - 375 umhos and 164.7 mg/L $CaCO_3$ respectively. These values were also high in the metalimnion where a high concentration of dissolved solids and bicarbonate alkalinity would provide a rich source of carbon and other nutrients for algal photosynthesis. And, indeed, a definite algal bloom was in evidence. Not surprisingly, the Secchi reading was very low; the second lowest value - 1.0 m.

The chlorophyll a value (2.85 ug/L) obtained at 0.0 m. is not nearly as high as one would expect from the other indicators of productivity. Also the ratio of chlor. a / pheo. is again very high (12.29) although here again the mixing involved in the turnover may be a cause since the algal sample was collected on 10/9 not on 9/25 and the lake may have turned over during that time. (No temperature measurements were taken at that time.) Unfortunately a survey for algal dominance was not made on Bowman II though the presence of blue-green algae would appear to be a certainty. Coelosphaerium was found in Bowman I so that this species would surely be found in Bowman II as well. Table 4 shows that several different blue-green species were among those in Waccabuc, so that all four lakes may be assumed to contain at least some of this eutrophication indicator.

The pH parameter is closely linked to alkalinity as can be seen in the relatively small range of values among the four lakes. (Table 2) Surface values varied only slightly over one unit (7.7—6.4) due to the buffering ability of the carbonate- bicarbonate- carbon dioxide alkalinity system. In the pH range from 6.4 to 7.7 the major proportion of carbon dioxide is in the form of bicarbonate ions. There was an expected decrease with depth in pH in Calder, Waccabuc (while stratified) and Bowman II due to increasing amounts of CO_2 present. The turnover in Waccabuc reversed the values (6.4 at 0 m. and 7.0 at 10 m.) perhaps by increasing the amount of bicarbonate.

Conclusion

The data bears out a Naumannesque first assessment of all the lakes at least to the extent that none of them “looked” like oligotrophic lakes by color or transparency. They are not. Nor are any of them deep enough (Thienemann) to be oligotrophic against the influx of nutrients from developing Westchester County. Or even to be “secondarily Oligotrophic”. (Lundbeck)

The lakes fit some where along the gradient in the mesotrophic to eutrophic range with Calder perhaps the least eutrophic and Bowman II, the most. The data seems to place Waccabuc close to Calder in trophic status now that the aerator is fighting its eutrophic drift, but the numbers of blue-green algae species present is an indication of the uphill nature of the battle. Bowman I appears to be less eutrophic than Bowman II and probably more than Calder and Waccabuc, though a more complete algal dominance survey would have helped in the assessment.

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