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TROPHIC ASSESSMENT OF TEN PUBLICLY-OWNED NORTHEASTERN OHIO LAKES

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Abstract. Trophic assessments of 10 publicly-owned northeastern Ohio lakes including Aquilla, Baldwin, Findley, Hinckley, Hodgson (Muddy), Spencer, Lower Shaker, Upper Shaker, Virginia Kendall, and Wallace indicated that all were highly eutrophic. Criteria for these assessments were based on a *Trophic State Index* developed by the U.S. Environmental Protection Agency that incorporated epilimnetic levels of total phosphorus, dissolved phosphorus, inorganic nitrogen, dissolved oxygen, and chlorophyll *a* and Secchi disk water transparency into a single numerical index of trophic status (TIN). The most eutrophic lakes were Spencer, which had been purposely enriched to increase productivity, and the Shaker Lakes, which were enriched by stormwater overflows of sanitary sewers. The least eutrophic lakes were Hodgson, Aquilla, Virginia Kendall, and Wallace reflecting relatively better watershed protection from soil erosion and domestic organic wastes.

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Section 208 of the Federal Water Pollution Control Act (Pl 92–500, 1972) provides for water quality management planning. The Governor of the State of Ohio designated the Northeast Ohio Areawide Coordinating Agency to carry out this planning in 7 northern Ohio counties. As part of the planning effort, the trophic status of 10 publicly owned lakes was determined. These lakes included Aquilla, Baldwin, Findley, Hinckley, Hodgson, Lower and Upper Shaker, (Horseshoe) Spencer, Virginia Kendall, and Wallace (fig. 1) where no previous comprehensive water quality information was available.

Classification of water bodies according to trophic status has been a widely accepted practice among limnologists. Three major categories, oligo-, meso-, and eutrophic, describing the degree of enrichment have been recognized. These terms, however, have come to be used in different ways by different investigators. For example, some investigators emphasize the relative nutrient flux available to aquatic plants, some refer to plant and animal production, and others emphasize the excess discharge of aquatic plant nutrients (Lee 1971). Reviews of the eutrophication process and its consequences include among others those of Sawyer (1966), AWWA (1966), Fruh *et al* (1966), Stewart and Rohlich (1967), Vollenweider (1968), National Academy of Science (1969), Rast and Lee (1978), and Likens (1972).

In recent years, numerous systems have been devised to expand the number of trophic categories and to develop numerical indexes rather than to rely on nomenclatural schemes. More categories are desirable because of the need to distinguish between similar lakes and to detect slight changes in trophic status of lakes undergoing renovation or degradation, Leuschow *et al* (1970), Piwoni and Lee (1975), and Carlson (1977).

Since differences in ranking among trophic indexes were regarded as relatively minor, the U.S. EPA trophic index system (TIN) was chosen for this study.

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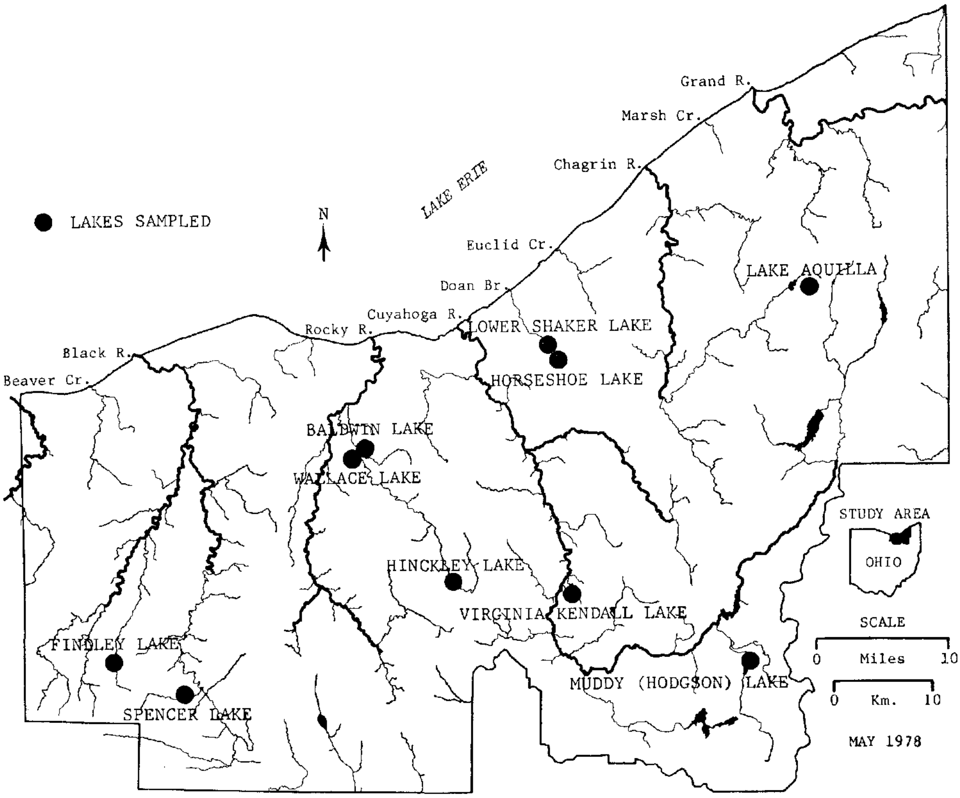

FIGURE 1. Map of northeastern Ohio showing location of lakes sampled for trophic assessment. NOACA Water Quality Management Planning Area.

The TIN has the advantage of a wider data base, more limnological parameters for comparative studies, and for water quality management planning purposes, it encompasses the parameters of interest to U.S. EPA lake restoration efforts (National Eutrophication Survey 1974).

DESCRIPTION OF LAKES

(See table 1 for morphometric data of area, volume, maximum and minimum depths, shoreline length, and shore development index.)

Lake Aquilla. Lake Aquilla is located 5 km southeast of Chardon in the marshy headwaters of the Cuyahoga River (fig. 1). The lake basin is a naturally formed depression in glacial outwash sand and gravel overlying a previously glaciated valley. Artesian wells account for much of the inflowing water. Lake Aquilla has a surface area of approximately 11 ha and a maximum depth of 4.5 m. These dimensions, however, are quite variable because of the highly variable quantity of inflowing water, the low-lying morphology of the immediate lakeshore, and the natural blockage of outflowing water caused by sedimentation and by constantly changing patterns of vegetative growth. The latter impediments to the outflow have been alleviated with the dredging of a channel to augment natural outflows.

The watershed consists mostly of woodlands and swampy areas with some residential and lightly-cultivated agricultural lands at higher elevations. Eroded soils from upstream regions and septic tank effluents from the village of Aquilla located on the west lakeshore appear to be major pollutants of the lake. Effluents from a sewage treatment plant southeast of Chardon also may be an important source of nutrient enrichment. The lake is operated by the Ohio Department of Natural Resources for fishing and boating.

Baldwin Lake. Baldwin Lake is an impoundment of the East Branch of the Rocky River in the City of Berea (fig. 1). The lake was constructed in 1936 for water-oriented recreation and is owned by the Cleveland Metropolitan Park District. The lakeshore is surrounded by open areas, wooded parkland, and residential areas. The upstream watershed is mostly lightly-cultivated agricultural land and open space with 19 to 20% woodland. There are no major sources of industrial pollution; however,

TABLE 1
Morphometric Data for 10 Publicly-Owned Northeastern Ohio Waterbodies.

Waterbody	Location*	Area (ha)	Volume (m^3)	Depth max (m)	Depth Mean (m)	Shore Length (m)	Shore Develop Index**
Lower Shaker	Shaker Heights	7.0	7.0×10^4	3.0	1.0	1590	1.69
Spencer	Lodi	22.5	3.1×10^5	2.4	1.4	3080	1.83
Upper Shaker	Shaker Heights	5.1	5.1×10^4	2.2	1.0	1360	1.69
Hinckley	W. Richfield	32.7	8.0×10^5	6.1	2.4	4470	2.20
Findley	Wellington	36.4	11.5×10^5	6.2	3.2	5340	2.49
Baldwin	Berea	12.4	4.7×10^4	2.0	0.4	2100	1.68
Hodgson	Kent	85.2	4.5×10^6	17.0	5.3	6530	1.99
Aquilla	Chardon	11.4	3.4×10^5	4.5	3.0	1970	1.64
Virginia Kendall	Peninsula	5.2	7.5×10^4	3.0	1.4	1230	1.53
Wallace	Berea	6.3	1.1×10^5	5.5	1.7	2360	2.66

*U.S.G.S. 7.5 min. Quadrangle.
**Ratio of length of shoreline to $2\sqrt{\pi \text{ area}}$.

there are 2 domestic wastewater treatment plants upstream. Pollutants are mainly eroded soils, septic tank and sewage treatment plant effluents.

Findley Lake. Findley Lake was completed in 1956 as an impoundment of the upper reaches of Wellington Creek, a tributary of the West Branch of the Black River (fig. 1). It is located approximately 3 km south of the town of Wellington. The lake is managed by the Ohio Department of Natural Resources, Division of Parks and Recreation, which maintains a public camping area and other recreational facilities on the lakeshore.

Findley Lake watershed consists mostly of heavily cultivated agricultural lands with some small wooded areas near the streams. Land immediately adjacent to the lakeshore is mostly wooded. The major pollutants of the lake are eroded soils and perhaps agricultural fertilizers. There are no known industrial pollutants or major sources of domestic wastewaters.

Hinckley Lake. Hinckley Lake, an impoundment of the East Branch of the Rocky River, was completed in 1938 to provide water-oriented public recreation (fig. 1). The lake is owned by the Cleveland Metropolitan Park District.

The shoreline is mostly wooded with a few open areas for swimming, sports and picnicking. Farther upstream the watershed consists mostly of lightly-cultivated agricultural lands and open space. Woodlands, especially along streams, account for approximately 40% of the watershed. Eroded soils from deforested lands and an upstream testing site for defense vehicles probably are the major pollutants of Hinckley Lake.

Hodgson Lake. Hodgson Lake (originally called Muddy Lake) is located approximately 4 km southwest of the City of Ravenna (fig. 1). The lake was originally a kettle-type glacial lake, but of much smaller size. In the 1840's a dam was constructed at the northwest outlet to provide additional water storage for the Ohio Canal system. At this time, a feeder canal also was constructed from Congress Lake outlet to ensure an adequate water supply into the lake. After the canals ceased operations, the lake water was used for industrial purposes, but in recent years, it has served as a reserve water supply for the City of Ravenna. The immediate lakeshore is mostly open space with a few wooded areas. Further upsteam the watershed consists mostly of lightly cultivated agricultural lands.

Lower and Upper Shaker Lakes. Lower and Upper Shaker Lakes are small impoundments of Doan Brook located between Cleveland Heights and Shaker Heights. The City of Cleveland owns both lakes but leases them to the 2 adjacent cities. The lakes were built in the mid-1800's, the Lower Lake to provide power for a sawmill and the Upper Lake to power a grain mill. In recent years, the lakes have been the center of activities for the Shaker Lake Regional Natural Center. Upper Shaker Lake is "U" shaped and usually is called Horseshoe Lake. The watersheds for both lakes are mainly residential with some wooded parkland. Major pollutants are stormwater overflows of sanitary sewers, lawn fertilizers, and debris from streets and park areas.

Spencer Lake. Spencer Lake was formed in 1960 by impounding a small tributary of the East Branch of the Black River near the village of Spencer (fig. 1). The lake provides public recreation and is owned by the Division of Wildlife of the Ohio Department of Natural Resources.

Spencer Lake is somewhat oval-shaped, but the northern ⅓ is separated from the southern ⅔ by a causeway with 3 steel culverts connecting the water. The watershed consists mostly of heavily-cultivated agricultural lands, but much of the immediate lakeshore is wooded. Except for possible inflow of eroded soils and agricultural fertilizers, Spencer Lake is relatively unpolluted.

Virginia Kendall Lake. Virginia Kendall Lake is an impoundment of Salt Run, a small tributary of the Cuyahoga River (fig. 1). The lake was built in the 1930's by the State of Ohio to provide public recreation. The lake has been under the control of the Akron Metropolitan Park District, but ownership recently has been transferred to the Cuyahoga Valley National Recreation Area. The watershed is mostly wooded parkland with open areas in the headwater region. No major pollutants except eroded soils and perhaps small amounts of septic drainage enter the lake.

Wallace Lake. Wallace Lake is located in the floodplain of the East Branch of Rocky River in the City of Berea (fig. 1). A portion of the basin is an abandoned quarry. The lake is owned by the Cleveland Metropolitan Park District and is used for public recreation. The west shore of the lake is entirely residential, but the east shore is mostly open parkland with a large swimming beach and parking lot. A narrow roadway separates the southeastern section of the lake from Baldwin Lake.

METHODS

Morphometric data for each lake included surface area, volume, depths, length of shoreline, and shoreline development index. Surface areas were determined from aerial photographs by grid-enumeration. Lake volumes (V) were calculated by summation of a series of truncated cones (Welsh 1948).

A numerical trophic index system (TIN) for classifying lakes and reservoirs developed by the U.S. Environmental Protection Agency (National Eutrophication Survey 1974) was calculated for each lake. This trophic index required analyses for total and dissolved phosphorus, inorganic nitrogen, dissolved oxygen, chorophyll *a* and Secchi disk transparency.

Water depths, depending upon the size of the lake, were determined at 15 to 25 uniformly spaced locations on each lake, using a weighted measuring line. Shoreline lengths (L) were determined from aerial photographs, and shoreline development indexes (SD) were calculated from the formula:

$$SD = \frac{L}{2\sqrt{\pi A}}$$

where A is the area of the lake (Welsh 1948).

Chemical-physical water analyses for each lake included alkalinity, pH, conductivity, ammonia, nitrogen, nitrate-nitrogen, total and dissolved phosphorus, chlorophyll *a*, and Secchi disk transparency. Methods for each chemical analysis were in accordance with *Methods for Chemical Analysis of Water and Wastes* (U.S. EPA 1974). Temperature and oxygen profiles were taken with a YSI 51A meter. Water samples for chemical analyses were taken from the epilimnion and from the hypolimnion at a single location near the geographic center of each lake during later summer and from the surface and mid depth during autumn overturn.

Phytoplankton samples were taken from the upper, middle, and lower portion of the photic zone with a 3 ℓ Kemmerer water bottle. The phytoplankton was preserved in Lugol's solution and allowed to settle in glass cylinders. The supernatant was removed to concentrate the organisms for identification and for estimates of cell volumes from microscopically measured dimensions of each genera (APHA 1975). Taxonomic keys and illustrations in Prescott's *Algae of the Western Great Lakes Area* (1962) were used for identification of phytoplankton.

The U.S. EPA *Trophic State Index* (Natl. Eutrophication Survey 1974) incorporates the parameters of total phosphorus, dissolved phosphorus, inorganic nitrogen, Secchi disk transparency, minimum dissolved oxygen, and chlorophyll *a*. Each of these parameters in one way or another reflects the trophic condition of a lake. For example, the concentrations of total phosphorus, dissolved phosphorus, inorganic nitrogen and chlorophyll *a* are assumed to be directly proportional to the degree of enrichment and hence eutrophication. Secchi disk transparency and minimum dissolved oxygen levels are assumed to be inversely proportional to the degree of eutrophy. Thus, Secchi disk readings and dissolved oxygen levels are subtracted from constants.

The *Trophic State Index* was developed from a data-base of analytical values for each of the six parameters from over 200 eastern and midwestern lakes. These lakes ranged from oligotrophic to extremely eutrophic in nature.

Calculation of a *Trophic State Index* requires a table matching selected values for each parameter with the percentage of data-base lakes exceeding each of the values selected. The entire range of expected values for each parameter has been divided uniformly into numerous levels or concentrations. For each level the percentage of data-base lakes exceeding that particular level has been calculated. This table then serves as the data-base for computing *Trophic Index Numbers* (TIN) for "unknown" lakes.

To determine a TIN for an "unknown" lake, analytical values for each parameter are obtained and the percentage of data-base lakes exceeding each of these values is obtained from the table. Mean values for epilimnetic samples are used for all parameters except for minimum dissolved oxygen concentrations. For dissolved oxygen, the lowest value recorded from any part of the lake is used. The overall TIN for an "unknown" lake is the sum of the percentile rankings for each of the 6 parameters obtained from the table.

In general, lakes with TIN values of 500–600 are considered to be in very good condition and fall within the oligotrophic category. TIN's of 420–499 correspond to the mesotrophic category. Lakes classified as eutrophic usually have TIN values below 420. Generally, the lower the TIN values, the greater is the magnitude and frequency of nuisance algal problems and other undesirable water quality conditions (Natl. Eutrophication Survey, 1974).

The value used in calculating TIN's for the present study was the mean of results obtained from the summer and autumn surveys. Analyses from the epilimnion only were used for total phosphorus, dissolved phosphorus, inorganic nitrogen, and chlorophyll *a*. For minimum dissolved oxygen concentrations, the lowest values obtained from the lake survey were used.

RESULTS AND DISCUSSION

Based on U.S. EPA *Tropic State Index values* (TIN), each of the water bodies in this study can be placed into one of 3 groups: Group I lakes TIN$\leq$100, Group II TIN=100–200, and Group III TIN$\geq$200 (fig. 2).

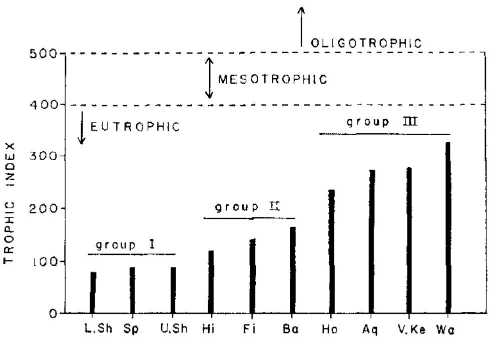

FIGURE 2. U.S. EPA Trophic Index Numbers (TIN) for 10 publicly-owned lakes of northeastern Ohio. L. Sh—Lower Shaker Lake, Sp—Spencer Lake, U. Sh—Upper Shaker Lake, Hi—Hinckley Lake, Fi—Findley Lake, Ba—Baldwin Lake, Ho—Hodgson (Muddy) Lake, Aq—Aquilla Lake, V. Ke.—Virginia Kendall Lake, Wa—Wallace Lake.

Group I Lakes. The most eutrophic lakes were Spencer, Lower Shaker, and Upper Shaker with TIN's ranging from 80–88 (fig. 2). These lakes were relatively alkaline with moderate epilimnetic conductivity of approximately 250–400 µmhos/cm. Dissolved and total phosphorus concentrations were very high with total phosphorus levels ranging from approximately 100–300 µg/ℓ (table 2). These levels in most cases exceeded phosphorus concentrations in more than 70% of the EPA data-base lakes (table 3).

Inorganic nitrogen concentrations were extremely high, especially in the Shaker Lakes where nitrate-nitrogen levels as high as 8.8 µg/ℓ were found (table 2). None of the EPA data-base lakes contained higher concentrations of inorganic nitrogen than the Shaker Lakes (table 3).

Dissolved oxygen levels less than 1 mg/ℓ occurred during summer in the near bottom waters of all Group I lakes. Surface waters usually were well-oxygenated except during autumn overturn in the Shaker Lakes when concentrations of only 5–6 mg/ℓ were encountered. These concentrations represented only 50% saturation and probably reflected the high levels of suspended oxygen-demanding materials from sediments or from storm sewer overflows. Because of low D.O. levels, Group I lakes ranked in the lowest quarter of the EPA data-base lakes (table 3).

Water transparencies were extremely low for the Shaker Lakes and for Spencer Lake as indicated by Secchi disk values of

TABLE 2

*Chemical-Physical Water Quality Data for 10 Publicly-Owned Northeastern Ohio Waterbodies.**

Waterbody	Alkalinity-total (mg/ℓ to pH 4.5)	pH Range	Conductivity (µmhos/cm)	Nitrogen (mg/ℓ) Ammonia	Nitrogen (mg/ℓ) Nitrate	Phosphorus (µg/ℓ) Total	Phosphorus (µg/ℓ) Dissolved	Secchi Disk (m)
	Su Au	Su Au	Su Au	Su Au	Su Au	Su Au	Su Au	Su Au
Lower Shaker	89–110	8.0–8.1	265–390	0.27–<.1	0.8–6.9	170–108	66– 51	0.6–0.3
Spencer	92– 95	8.3–7.5	360–310	0.01– 0.3	0.6–1.2	308– 70	75– 14	0.4–0.4
Upper Shaker	92–119	8.7–8.1	320–390	0.11–<.1	0.2–8.8	238–200	21– 45	0.4–0.4
Hinckley	103–144	8.2–8.1	320–350	0.04– 0.1	1.4–1.8	176– 40	25– 14	0.3–0.5
Findley	78– 87	8.8–8.0	310–320	0.56–<.1	0.2–0.6	74– 76	39– 20	1.2–1.0
Baldwin	114–146	8.0–8.0	550–580	0.02– 0.2	1.3–2.3	344–442	104–278	0.1–0.1
Hodgson	70– 77	7.8–7.4	360–330	0.08–<.1	0.4–0.8	122– 40	19– 10	1.9–1.4
Aquilla	63– 57	6.9–7.8	120–180	0.09 –0.1	1.0–0.6	43– 30	19– 10	1.6–2.0
Virginia Kendall	135–176	7.9–8.1	450–670	0.05–<.1	1.4–2.2	44– 37	10– 10	2.0–1.5
Wallace	73– 77	8.1–7.7	900–940	0.09– 0.4	0.8–2.1	14– 22	5– 10	2.0–0.8

*Analyses were made from epilimnetic samples taken near the geographic center of each water body. Values shown in the left column (Su) for each parameter are means of 2 analyses from late summer 1977. Those in the right column (Au) are means of 2 analyses from mid-autumn 1977.

TABLE 3
*Rank of 10 Publicly-Owned Northeastern Ohio Waterbodies Using U.S. Environmental Protection Agency Trophic State Index System.**

	Relative Ranking (%)						
	Total Phos.	Dissolved Phos.	Inorganic Nitrogen	15-Min Dissol. O_2	500-Secchi Disc Depth	Chlorophyll *a*	Trophic Index No.
Lower Shaker	23	26	0	2	7	22	80
Spencer	19	31	9	5	6	16	86
Upper Shaker	17	37	0	21	6	7	88
Hinckley	28	57	2	2	6	27	122
Findley	34	41	17	2	33	16	143
Baldwin	9	14	1	65	0	74	163
Hodgson	32	63	17	2	55	67	236
Aquilla	57	66	9	5	62	74	273
Virginia Kendall	55	77	2	5	60	79	278
Wallace	77	84	1	21	48	92	323

*Numbers indicate % of EPA data-base lakes with higher values. *Trophic Index Number* (TIN) is the sum of 6 parameters listed. Lower values indicate a higher degree of eutrophication.

approximately 0.5 m (table 2). Dense growths of phytoplankton probably were major causes of high turbidities in August, but in October, because of thermal overturn, suspended sediments probably were important components of the turbidity.

The dominant summer phytoplankton of Lower Shaker Lake were species of the cyanophytes, *Anabaena*, and *Oscillatoria*, the cryptophyte, *Cryptomonas*, and the diatom, *Cyclotella*. *Chlorophytes*, especially *Actinastrum* and *Scenedesmus*, and euglenophytes, *Lepocinclis* and *Trachelomonas*, also were abudant. In Upper Shaker Lake, *Oscillatoria* accounted for more than 70% of the total cell volumes. The major phytoplankton of Spencer Lake also was *Oscillatoria*, but the chlorophytes *Ankistrodesmus*, *Pediastrum*, and *Scenedesmus* were abundant. Euglenophytes, *Cryptomonas* and *Chrysococcus*, also were common. These genera of algae, especially the great abundance of cyanophytes and chlorophytes and the large densities of summertime diatoms, were indicative of highly eutrophic conditions with nutrient enrichment (Hutchinson 1967, Palmer 1969). The large volumes of euglenophytes also were probable evidence of organic enrichment. Total summer phytoplankton volumes of approximately 20–30 mm³/ℓ and chlorophyll *a* levels of 40–100 μg/ℓ (table 4) for Group I lakes were indicative of highly eutrophic conditions (Likens 1975, Wetzel 1975).

TABLE 4
Phytoplankton Biomass and Chlorophyll a for 10 NE Ohio Lakes.

Lake	August 1977		October 1977	
	Biomass (mm³/ℓ)	Chloro. *a* (μg/ℓ)	Biomass (mm³/ℓ)	Chloro. *a* (μg/ℓ)
Lower Shaker	27.2	43.2	1.7	11.0
Spencer	22.8	58.9	2.3	9.4
Upper Shaker	27.2	98.9	2.6	21.9
Hinckley	2.1	30.8	0.1	8.1
Findley	54.4	43.0	33.5	22.3
Baldwin	0.3	10.9	1.9	3.0
Hodgson	1.3	5.8	11.0	10.2
Aquilla	1.4	10.6	0.8	3.1
Virginia Kendall	2.4	5.2	0.9	5.8
Wallace	5.6	3.0	0.7	2.3

The major cause of hypereutrophication in Spencer, Lower Shaker, and Upper Shaker Lakes was nutrient enrichment. In the case of the Shaker Lakes, the principal sources of nutrients probably were stormwater overflow from sanitary sewers. Agricultural fertilizers may have been an important source of nutrient enrichment in Spencer Lake; however, the fertility of the lake was purposely increased with straw by the Ohio Division of Wildlife.

Group II Lakes. Group II lakes with TIN's between 122–163 included Baldwin, Findley, and Hinckley (fig. 2). All 3 lakes are impoundments of small streams with rather extensive watersheds. Although these lakes had similar TIN's, the relative rankings for individual parameters were considerably different for Baldwin Lake than for Findley or Hinckley Lake (table 3).

For example, all Group II lakes were moderately alkaline with relatively high nitrate and total phosphorus concentrations (table 2). The major differences between Baldwin Lake and Hinckley and Findley Lakes were the much higher D.O. levels and extremely low water transparencies of Baldwin Lake. Conductivity and total phosphorus levels also were somewhat higher in Baldwin Lake.

Summer phytoplankton volumes of less than 1 mm^3/ℓ and chlorophyll *a* concentrations of 10.9 $\mu g/l$ for Baldwin Lake were relatively low, contrasting sharply with relatively large phytoplankton volumes of 2.1–54.4 mm^3/ℓ and chlorophyll *a* concentrations of 30.8–43 $\mu g/\ell$ for Hinckley and Findley lakes respectively (table 4).

These differences probably reflected the more lotic nature of Baldwin Lake. Compared to Findley and Hinckley Lakes, the relatively rapid more turbulent flow of water through Baldwin Lake maintained higher D.O. levels but also caused much greater turbidity. High turbidities undoubtedly were a major factor in limiting phytoplankton growth in Baldwin Lake.

Phytoplankton composition of Group II lakes was mostly indicative of highly eutrophic conditions (Hutchinson 1967). The major summer phytoplankton of Baldwin Lake were species of diatoms, *Cyclotella* and *Navicula*, and blue-green algae, *Oscillatoria* and *Spirulina*. Several genera of chlorophytes and euglenophytes also were common. In October, diatoms and *Oscillatoria* increased in quantity as did the euglenophytes, *Euglena* and *Phacus*. Chlorophytes were rarely observed in October samples. The nature of the phytoplankton composition reflected both the lotic and lentic nature of Baldwin Lake. The large proportion of diatoms in summer was more characteristic of a lotic environment, but the presence of blue-green algae was more characteristic of lentic environments. The diatom increase in October was typical of both lotic and lentic habitats, but the increase in euglenophytes and *Oscillatoria* was typical of enriched lentic environments (Hutchinson 1967, Palmer 1969, Hynes 1970).

The major summer genera of Findley Lake were the blue-greens *Anabaena*, *Ancystis*, and *Oscillatoria*. The diatom *Melosira* also was abundant. During October, a large mass of *Gomphosphaeria* developed, while other blue-greens declined. Diatoms also declined in biomass during the autumn, but the number of taxa increased.

The dominant summer phytoplankton of Hinckley Lake were species of *Oscillatoria*, the euglenophytes, *Lepocinclis* and *Trachelomonas*, and the diatom, *Cyclotella*. In October, blue-green algae and euglenophytes declined in quantity and variety of taxa, while diatoms increased in variety of taxa but declined in quantity.

Group III Lakes. Group III lakes with TIN's between 263–323 included Aquilla, Hodgson, Virginia Kendall, and Wallace (fig. 2). These lakes were slightly to moderately alkaline with pH values ranging from 6.9–8.1. Conductivities for Aquilla Lake and Hodgson Lake were relatively low, ranging from 120–360 μmhos/cm, but conductivities of Virginia Kendall and Wallace Lakes were higher, ranging from 450–940 μmhos/cm. Total and dissolved phosphorus concentrations were relatively low compared to other lakes in this study. Inorganic nitrogen levels were very high in all Group III lakes (table 2).

Dissolved oxygen levels less than 1–2

mg/ℓ occurred in the bottom waters of all 4 lakes. Secchi disk transparencies were more favorable for Group III lakes than for Group I and II lakes (table 3).

Summer phytoplankton cell volumes ranging from 1.4–5.6 mm^3/ℓ and chlorophyll *a* levels of 3.0–10.6 $\mu g/\ell$ were comparatively low (table 4). The phytoplankton composition of the Group III lakes was mostly indicative of mesotrophic or slightly eutrophic conditions (Hutchinson 1967). The dominant summer phytoplankton of Aquilla Lake included *Cryptomonas*, *Cyclotella*, *Asterionella*, and *Ochromonas*. In Hodgson Lake, the summer phytoplankton consisted mostly of *Anabaena*, *Gomphosphaeria*, and *Oscillatoria rubescens*. During the autumn overturn, the quantity of *O. rubescens* increased markedly as metalimnetic populations were mixed into the epilimnion. The dominant phytoplankton of Virginia Kendall Lake included *Anacystis*, *Oscillatoria*, *Cryptomonas*, and a few diatoms, especially *Cyclotella*. *Cryptomonas* accounted for more than 70% of the total cell volume during August and after the autumn overturn.

The major summer phytoplankton of Wallace Lake were *Euglena*, the cyanophytes *Anacystis* and *Oscillatoria*, *Cryptomonas*, and several genera of chlorophytes. In October, most of the same organisms were present except in reduced numbers.

The overall more favorable water quality and trophic status of Aquilla, Hodgson, Virginia Kendall, and Wallace Lakes reflected the relatively better managed watersheds of these lakes. Much of the land immediately adjacent to these lakes is well-protected from soil erosion by woodlands, marshes, and early successional vegetation. Large-scale agricultural activities are minimal, and domestic septic tank drainage is moderate.

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