Report presented at Michigan Academy meetings
April 17, 1953. Revised for Institute report.

Original: Fish Division
cc: Education - Game
Institute for
Fisheries Res.
C. T. Yoder
F. F. Hooper

INSTITUTE FOR FISHERIES RESEARCH
DIVISION OF FISHERIES
MICHIGAN DEPARTMENT OF CONSERVATION
COOPERATING WITH THE
UNIVERSITY OF MICHIGAN

ALBERT S. HAZZARD, PH.D.
DIRECTOR

ADDRESS
UNIVERSITY MUSEUMS ANNEX
ANN ARBOR, MICHIGAN

May 15, 1953

Report No. 1372

LIMNOLOGICAL FEATURES OF WEBER LAKE, CHEBOYGAN COUNTY, MICHIGAN

by

Frank F. Hooper

ABSTRACT

Observations made of Weber Lake, Cheboygan County, Michigan reveal that the lake is unique in having the lowest concentration of hydrogen ion, bicarbonate, calcium, magnesium, sodium, potassium and sulfate in the thermocline region. The alkalinity of the lake water is unusually low as compared with surrounding ground water and with other lakes of this region. Evidence is presented which suggests that the lake basin is sealed so that its alkalinity is not influenced by surrounding ground water, other than seepage water entering from an adjacent bog.

The lake is poor in phytoplankton and zooplankton. Rooted plants occur only at the lake margin. Midges and fingernail clams are the predominant bottom fauna organisms of deeper water in late summer. Midge larvae made up 87.1 percent of the volume of food in brook trout stomachs collected in August, 1952. Most of the food organisms identified from trout stomachs were species which occur only in deep water (between 10 and 39 feet). The growth rate of brook trout improved considerably following the removal of warm-water fish. Annual stocking with 15,000 fingerling brook trout has provided good fishing, particularly in the early part of the season, and has made the lake very attractive to sportsmen.

Because of the high concentration of iron in the bottom water, fertilization is not recommended as a management procedure. Alkalinization appears to be a more useful type of treatment for lakes of this type but should be attempted only on the experimental basis until its effectiveness can be ascertained.

Report presented at Michigan Academy meetings
April 17, 1953. Revised for Institute report.

Original: Fish Division
cc: Education - Game
Institute for
Fisheries Researc
C. T. Yoder
F. F. Hooper

INSTITUTE FOR FISHERIES RESEARCH
DIVISION OF FISHERIES
MICHIGAN DEPARTMENT OF CONSERVATION
COOPERATING WITH THE
UNIVERSITY OF MICHIGAN

ALBERT S. HAZZARD, PH.D.
DIRECTOR

ADDRESS
UNIVERSITY MUSEUMS ANNEX
ANN ARBOR, MICHIGAN

May 15, 1953

Report No. 1372

LIMNOLOGICAL FEATURES OF WEBER LAKE, CHEBOYGAN COUNTY, MICHIGAN

by

Frank F. Hooper

In the course of surveys of Michigan lakes carried on by the Institute for Fisheries Research of the Michigan Department of Conservation, observations were made upon a lake with unusual limnological features. These features are: (1) a type of chemical stratification in which pH and concentration of many electrolytes are lowest in the thermocline region, and (2) unusually low alkalinity in comparison with surrounding ground water and with other lakes of lower Michigan.

There are few references in the literature to natural lakes with dichotomous chemical stratification. Wiebe (1939) reports that in an impoundment having a large inflow of stream water, density currents may produce anomalous stratification of pH, alkalinity, and dissolved oxygen. The subject of dichotomous stratification of pH of lakes has been reviewed by Ohle (1934). He describes stratification of this type in three north German bog lakes. Yoshimura (1932) found dichotomous pH stratification in a series of Japanese lakes poor in calcium. Juday, Birge and Meloche (1935) describe a similar type of stratification in Lake Mary, a northeastern Wisconsin lake. The subject of the chemical dissimilarity of lakes and their surrounding ground waters has been discussed by Broughton (1941).

Weber Lake is located in Section 31, Township 34 North, Range 1 West, in southwestern Cheboygan County. Land surrounding the lake is entirely state-owned. Trout were planted following a partial biological survey made by the Institute for Fisheries Research in 1943. Growth of planted trout was poor in the presence of populations of stunted bluegills and perch. In 1948 the lake was poisoned with rotenone and restocked with trout. The present study of the lake was started during the summer of 1950 under the sponsorship of the University of Michigan Biological Station. Two series of physical and chemical observations, along with collections of plankton and bottom fauna, were made during August, 1950. Further observations were made on July 25, 1951. Between August 15 and August 21, 1952, a more intensive study of the physical and chemical features of the lake was carried on and a quantitative biological inventory of the lake was completed. This work was sponsored by the Institute for Fisheries Research of the Michigan Department of Conservation.

Mr. William Hazen, Department of Zoology, University of Michigan; Dr. Howard A. Tanner, Colorado A and M College; and Mr. Richard Sides, Michigan Department of Conservation, assisted at various times in the field work. Dr. Paul Barrett, Michigan State College, and the staff of the Michigan Department of Health Laboratory, Lansing, Michigan, aided in the mineral analysis of water samples.

PHYSIOGRAPHY

Weber Lake lies within a belt of high moraine covering southwestern Cheboygan County and eastern Charlevoix County. The lake occupies a deep pocket in the moraine. Surrounding land rises 20 to 30 feet above the water, except at the northwest extremity. Here a low-lying strip of land connects the lake with a *Sphagnum* bog to the west. A road now crosses this strip, but the peaty nature of the soil on either side of the roadway indicates that the bog was formerly an arm of the lake which has been filled in by the accumulation of peat. The lake has no active inlet or outlet, but receives seepage from the peaty soil connecting the lake with the adjacent bog. In June, 1950, a small flow of seepage water was observed entering the lake from this area. By August, this flow had ceased.

The lake has a surface area of 31 acres, a mean depth of 20 feet, and a maximum depth of 41 feet. The lake basin slopes most abruptly between the surface and the 15-foot contour. Thus the shoal area is small compared to the surface area. Bottom soils from the water's edge to a depth of 4 feet are chiefly of fine sand. In certain areas, the sand layer is less than an inch thick, and overlays a layer of soft ooze. The sediments of deeper water are of soft reddish-brown ooze.

METHODS

Temperature measurements were made with an electrical resistance thermometer. The underwater photometer described by Greenbank (1945) was used to measure light penetration. A portable battery-operated conductivity bridge was used for conductivity measurements. All measurements of pH were made with a Beckman pH meter (Model G). Oxygen, carbon dioxide, methyl orange alkalinity, hydrogen sulphide, iron, and sulphate determinations were made in accordance with procedures outlined in *Standard Methods for the Examination of Water and Sewage* (1946). A Beckman flame photometer was used in determinations of sodium, potassium, calcium and magnesium. A Klett-Summerson colorimeter was used to measure color, turbidity, and to make colorimetric determination of phosphorus. Water samples were centrifuged in a Foerst Plankton centrifuge to concentrate plankton organisms. A Juday plankton trap was used to make net plankton collections. Duplicate hauls were made at each depth. Bottom samples were collected with a 6 x 6 inch Ekman dredge.

PHYSICAL AND CHEMICAL CHARACTERISTICS

Temperature

Lake temperatures during the late summer of 1950, 1951 and 1952 are indicated in figures 1-3. Temperatures of the epilimnion did not exceed 72° F. in any of the observations. The upper limit of the thermocline varied in position between 14 and 20 feet, and its lower limit varied between 26 and 32 feet. Strata of temperature and oxygen concentration suitable for trout were present each of the three summers. Water of temperature less than 70° F. and with an oxygen concentration greater than 4 p.p.m. was found between 13 and 22 feet on August 9 and August 14, 1950; between 16 and 25 feet on July 25, 1951; and between 20 and 29 feet between August 13-16, 1952.

Transparency

Secchi disc readings of August 9 and August 14, 1950, ranged between 19 and 21 feet. On August 13, 1952, the reading was 19 feet, 8 inches. On that date, measurements made with the underwater photometer showed that 10 percent of the surface light penetrated to a depth of 21 feet. According to the transparency classification of Birge and Juday (1930), these measurements indicate a high-medium range of transparency. Although the epilimnion was quite transparent and contained small amounts of organic coloring matter, water of the hypolimnion was highly colored. On August 13, 1952, color of the surface water was 12 (expressed

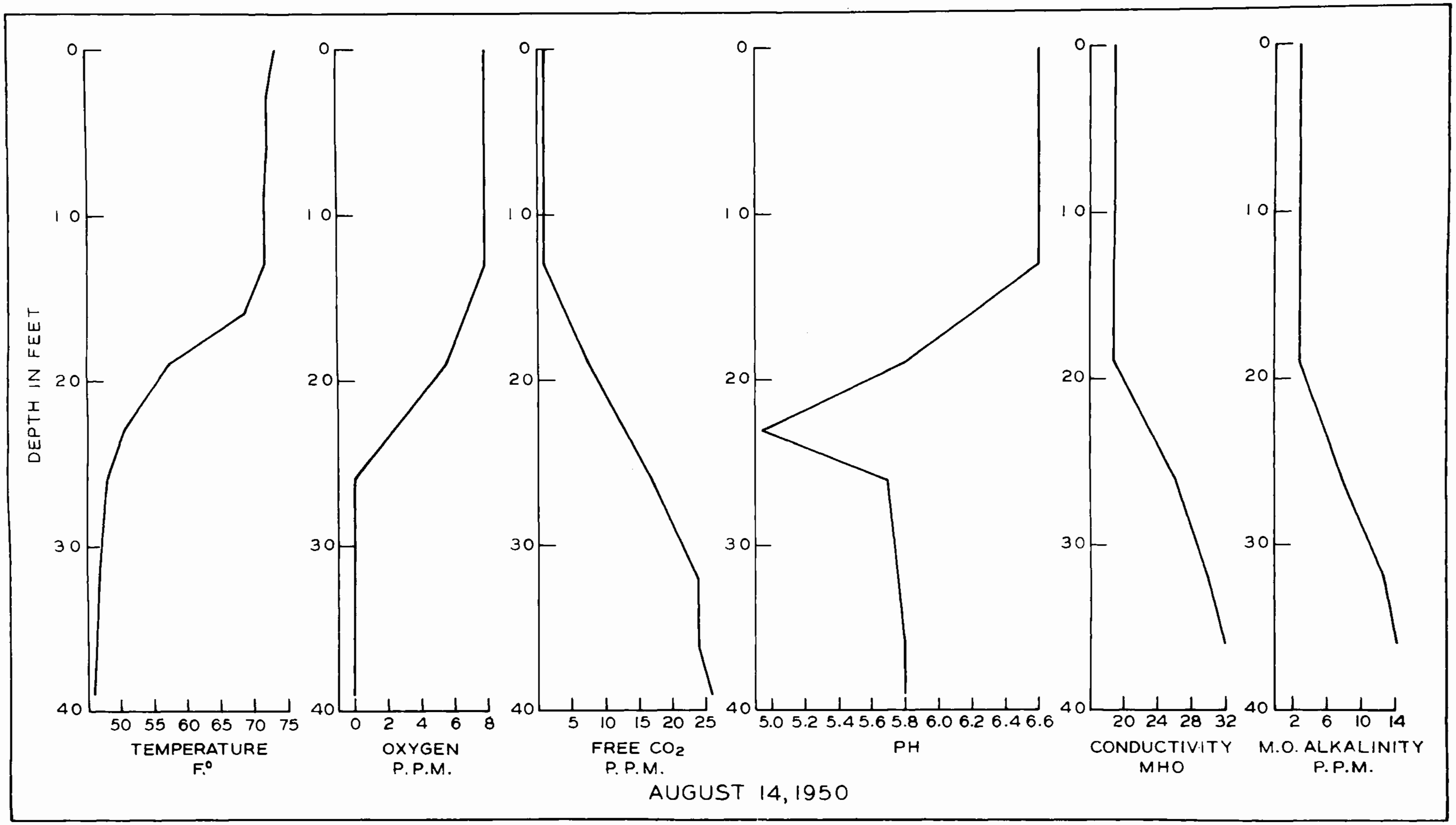

Figure 1. Physical and chemical features on August 14, 1950.

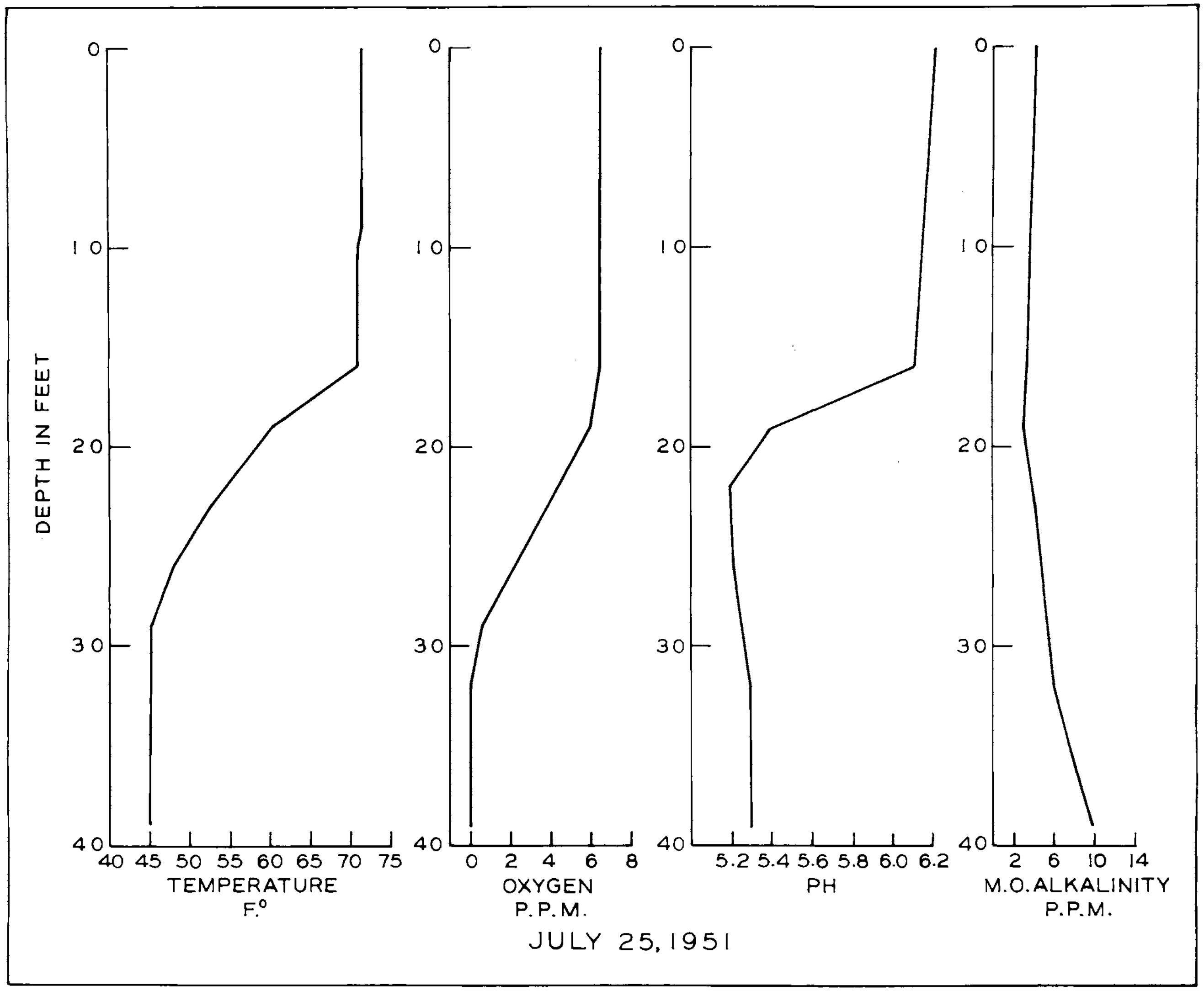

Figure 2. Physical and chemical features on July 25, 1951.

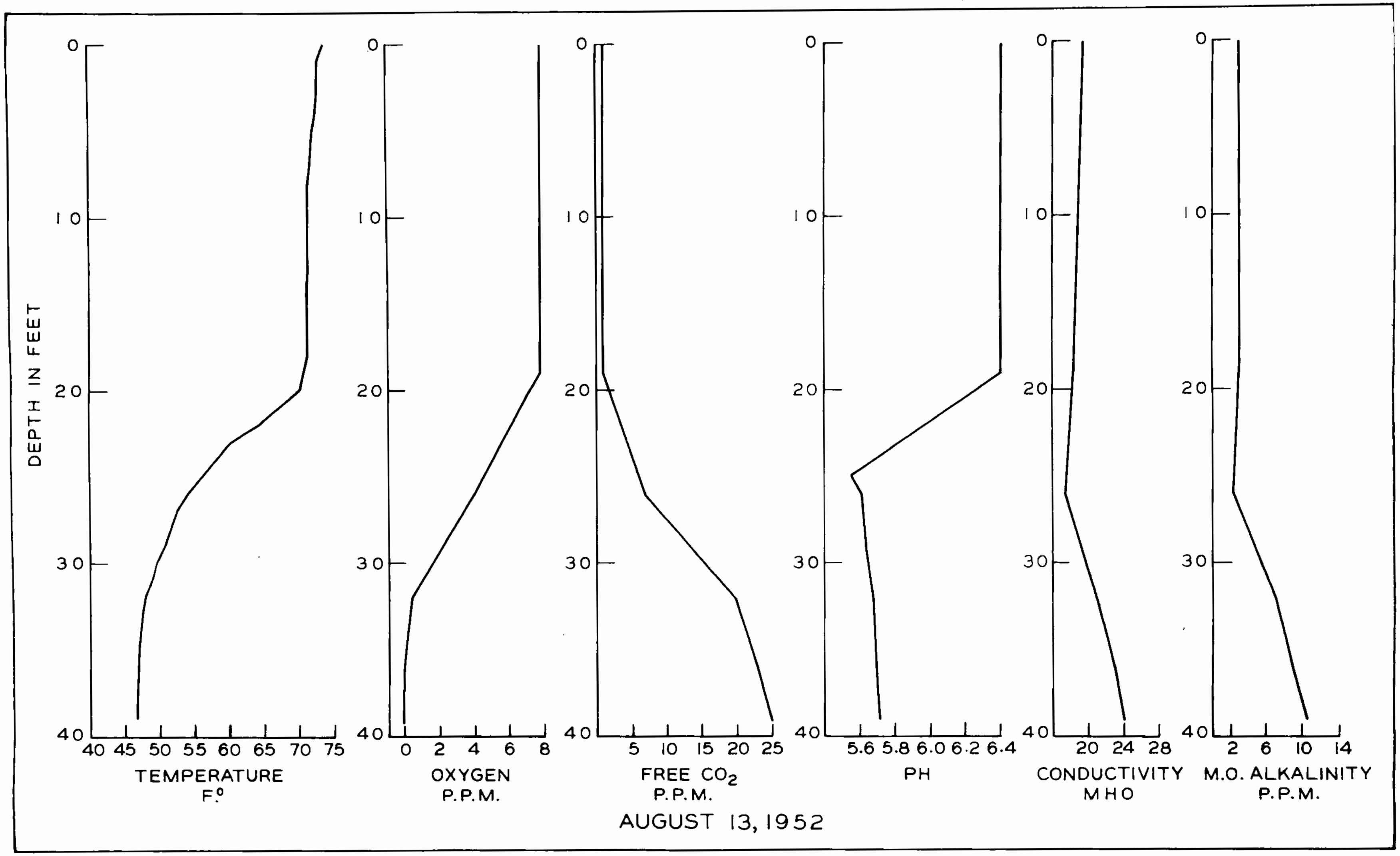

Figure 3. Physical and chemical features on August 13, 1953

on the platinum cobalt color scale). At the lower limit of the thermocline, the color had increased to 81. In the bottom water, it was 93.

Alkalinity and Conductivity

The methyl orange alkalinity of the epilimnion varied between 3 and 4 p.p.m. On July 25, 1951, and on August 13, 1952, the lowest alkalinity values were encountered in the middle part of the thermocline. On the latter date, the lowest conductivity readings also occurred in the mid-thermocline region (Figure 3). Alkalinity increased in the lower part of the thermocline, and in the hypolimnion. The alkalinity of the bottom water ranged between 10 and 15 p.p.m. Specific conductance varied between 19 and 21 mho in the epilimnion, and between 24 and 32 mho in the bottom water.

Hydrogen-ion Concentration

Dichotomous stratification of pH was observed during the summers of 1950, 1951 and 1952 (figures 1-3). The pH of the epilimnion varied between 6.1 and 6.7 in successive years. The lowest pH readings were in the thermocline between 22 and 25 feet; in this stratum pH ranged from 4.9 to 5.5. An increase in pH occurred in the lower thermocline and hypolimnion. The pH of the bottom water varied between 5.7 and 5.9. Although the pH minimum appeared at approximately the same depth each summer (22 to 25 feet), its position varied considerably in relation to the anaerobic zone and the lower limit of the thermocline. In 1950, the minimum occurred immediately above the anaerobic zone, and a large increase in pH appeared at the upper limit of the oxygen-free water. In 1951 and 1952, the lowest pH reading was approximately 10 feet above the anaerobic zone. In these years, a comparatively small increase in pH occurred immediately below the minimum value, and an additional small increase was apparent at the boundary of the oxygen-free water. On August 13, 1952, the pH minimum coincided with minima in the conductivity and alkalinity curves. On July 25, 1951, there was an apparent minimum in alkalinity immediately above the pH minimum. The data of August 14, 1950 give no indication of minima in either conductivity or alkalinity in the thermocline. However, none of the determinations were made at the exact depth of the pH minimum. Comparison of the alkalinity and pH data of 1950 with that of 1951 and 1952 shows that there was a greater increase in both alkalinity and pH with depth in the lower thermocline and hypolimnion in 1950 than in 1951 and 1952.

In Lake Mary, Juday, Birge and Meloche (1935) observed a well-defined pH minimum in the thermocline on two successive years. In three additional series of observations the pH minimum was not detected. In Lake Mary and in the Japanese lakes studied by Yoshimura (1932), the pH minimum always appeared in the layer just above the anaerobic zone. Yoshimura believed that the pH increase in the oxygen-free water below this stratum was caused by the action of free carbon dioxide upon calcium, iron and magnesium compounds present in the bottom deposits. This process was believed to release bicarbonates into the water. Juday *et al.* (1935) observed that the increases in bicarbonates and specific conductivity in the hypolimnion of Lake Mary were much the same when dichotomous pH stratification occurred as when it was absent. They concluded that some as yet unknown factor or factors played a part in producing this phenomenon. In Weber Lake, the increase in pH below the minimum reading was clearly greater in 1950 when the anaerobic zone was of maximum thickness, and when there was a comparatively large increase in alkalinity within the hypolimnion. This observation tends to support Yoshimura's belief that the increase in pH of the bottom water of soft-water lakes with dichotomous pH stratification is due to the leaching of bicarbonate from the bottom mud by carbon dioxide.

Minerals

The data of July 21, 1951 and August 13, 1952 indicated that conductivity and alkalinity were lowest in the middle part of the thermocline. This suggests that the mineral content of water of this stratum was lower than that of the remaining lake water. To verify this apparent minimum of electrolytes, determinations of the concentration of iron, magnesium, calcium, sodium, potassium and sulphate were made on a vertical series of water samples collected on August 13, 1952 (Table 1). Minimum concentrations of all substances except iron were found at the 26-foot depth. The amount of sodium above 26 feet differed only slightly from that present in the hypolimnion. Potassium was somewhat higher below the 26-foot minimum than in the epilimnion. Magnesium, iron and bicarbonate increased steadily in the lower thermocline and hypolimnion. The calcium increase in this region was less than the increase of magnesium and iron. Thus the alkalinity increase noted in the lower thermocline and hypolimnion appears to be due chiefly to an increase in the bicarbonates of magnesium and iron, rather than calcium. Sulphate decreased from 6 p.p.m. at the surface to 2 p.p.m. at 26 feet. At 32 and 36 feet, the concentration was nearly as great as at the surface (5 p.p.m.). The concentration of sulphate at 26 feet appears to be proportionately lower than other minerals. This suggests that sulphur bacteria may have lowered the concentration by reducing sulphate to hydrogen sulphide. Hydrogen sulphide, however, was not detected chemically or by odor at this depth, although it was present at 36 and 39 feet.

Table 1.--Mineral content of Weber Lake water at various depths on August 13, 1952

Depth in feet	Bicarbonate p.p.m.	Conductivity in reciprocal megohms	Sulphate p.p.m.	Potassium p.p.m.	Sodium p.p.m.	Calcium p.p.m.	Magnesium p.p.m.	Iron p.p.m.
0	1.8	19.7	6.0	0.5	2.7	1.3	0.1	0.00
19	1.8	18.5	4.0	0.6	2.9	1.4	0.6	0.00
26	1.5	17.7	2.0	0.4	2.5	0.9	0.1	0.11
32	4.0	21.0	5.0	0.8	2.6	1.4	1.4	0.55
36	4.4	23.0	5.0	0.8	2.6	2.0	1.6	0.77
39	5.6	24.0	4.4	1.5	2.7	1.6	2.0	0.85

Table 2.--Physical and chemical data of August 15, 1952

Depth in feet	Hydrogen sulphide p.p.m.	Total phosphorus micrograms per liter	Sestonic phosphorus micrograms per liter	Inorganic phosphorus micrograms per liter	Color p.p.m.	Turbidity p.p.m.
0	0.0	10	2	+	12	1
19	0.0	12	2	+	12	3
26	0.0	16	7	+	18	6
32	0.0	30	14	+	72	25
36	0.33	50	-	+	81	30
39	0.67	50	34	1.0	93	30

\+ Indicates concentration less than 1.0 microgram per liter.

There were no indications that biological activity within the open water brought about the electrolyte deficiency at 26 feet. Water at this depth contained little living plankton and the seston concentration was less than at 20 feet. The electrolyte deficiency appears therefore to be the result of either (1) chemical processes removing electrolytes at the mud surface, or (2) subsurface inflow of water low in electrolytes.

Relationship of Lake Water to Surrounding Ground Water

The unusual softness of the lake water is well known to the farmers of the surrounding region, some of whom use lake water for domestic purposes in their homes rather than well water which required softening. Ground water of the surrounding area is much higher in alkalinity than the lake water. Well water at the Department of Conservation cabin at the south end of the lake has an alkalinity of 150 p.p.m. At the camp ground northeast of the lake, well water has an alkalinity of 180 p.p.m. Both of these wells lie within 150 feet of the lake. This chemical dissimilarity between the lake water and the surrounding ground water suggests that the lake basin is effectively sealed from the ground water. Broughton (1941) describes a similar dissimilarity in the bound carbon dioxide content of certain northeastern Wisconsin seepage lakes and surrounding ground water. His work indicates that clays present in the original lake basin and later organic deposits formed a basin seal which effectively isolated the lake water from ground water. Water entering Weber Lake thus must arise principally from direct precipitation, surface runoff and seepage.

Sphagnum peat is known to remove bases from water and to set free acids (Ruttner, 1953). Welch (1938) believed that peaty material derived from Sphagnum in the deeper part of Vincent Lake was able to establish and maintain a highly acid reaction in the lake water. The reduced electrolyte content of water in the mid-thermocline region may be due either to contact of this water with submerged peat beds within the lake basin or to subsurface seepage entering from the adjacent bog. Either of these processes would tend to reduce the electrolyte content and to lower the pH of the water stratum affected.

BIOLOGICAL CHARACTERISTICS

Rooted Aquatic Vegetation

A list of aquatic plants of the lake includes 18 species. Of this number, all but three were marginal species, growing along the shore in water less than 6 inches deep. The yellow water lily *Nuphar variegatum*, *Vallisneria americana*, and a species of *Sagittaria* were the only species found in deeper water. Most of the shoal area had no rooted aquatic vegetation. *Nuphar* and *Vallisneria* were found chiefly in the small bay at the southeast corner of the lake.

Little of the marginal vegetation was of the bog type. Patches of *Sphagnum* were present on decaying logs at the water's edge, and isolated clumps of *Andromeda* and *Chamaedaphne* were found several feet above the present water level.

Plankton

Phytoplankton of the lake consisted chiefly of members of the Dinophyceae and Chrysophyceae. *Peridinium wisconsinensi*, *Glenodinium* sp. and *Dinobryon sertularia* were numerically dominant in samples taken on June 23, 1950. Dinoflagellates were again predominant in the collections of August 13, 1950 and August 15, 1952, although the numbers of *Dinobryon* were greatly reduced. Diatoms were either rare or absent in all of the collections. Desmids were present in nearly all samples but were not abundant. The average volume of phytoplankton of the epilimnion on August 15, 1952 was 923,000 standard cubic units per liter. Algae were most abundant in samples collected at 10 feet (Table 3). The average ash-free dry weight of seston collections made at the surface and at depths of 10 and 20 feet was 1.31 mg. per liter.

Rotifers were predominant among zooplankters. Twelve genera of rotifers were recorded from the net plankton. The samples of June 23, 1950 contained six species of Entomostraca, of which Polyphemus pediculus and Holopedium gibbernum were most abundant. Collections made in late summer contained few Entomostraca. On August 25, 1950, only three species were recorded, and the average number of individuals of all species was less than 10 per liter. On August 14, 1952, 80 liters of lake water (duplicate 10-liter plankton trap collections at each of four depths) contained only a single specimen of Holopedium.

Bottom Fauna

The volume of bottom fauna of collections made on August 17, 1952 ranged between 0.06 ml. per square foot (39 feet) and 1.48 ml. per square foot (3-6 feet). Maxima in volume occurred between 3 and 6 feet, and between 19 and 22 feet (Table 4). Gomphine dragonfly nymphs made up 85 percent of the total volume at the former depth interval. The sublittoral concentration consisted chiefly of the midge. Tendipes plumosus and the fingernail clam Pisidium sp. Pisidium was the most abundant animal in all collections made above 22 feet. Midge larvae (Polypedilum sp., Calopsectra sp.) were numerous in the littoral zone, but comprised only a small percentage of the total volume. Below 26 feet, the midges Tendipes plumosus and Chaoborus punctipennis were the only organisms of quantitative importance.

Table 3.--Plankton and seston at various depths on August 25, 1952

Depth	Centrifuged plankton (3 liter samples)				Net plankton 2 samples at each depth (20-liter)	
	Phytoplankton			Seston		
	Cells of colonies per liter		Volume in[1] thousand cubic units per liter	Ash-free dry weight mg. per liter	Number of organisms per liter	Ash-free dry weight mg. per liter
	Dinophyceae	Chrysophyceae				
0	4,800	1,390	351	0.97	320	0.30
10	3,800	8,280	1,465	1.44	325	0.23
20	8,160	5,570	853	1.53	370	0.20
26	4,060	770	171	1.36	460	0.26

[1] 1 cubic unit = 8,000 cubic microns

Table 4.--Volume and number of bottom organisms at various depths on August 17, 1952

Bottom organisms	3-6 Feet 4 samples			6-10 Feet 4 samples			13-16 Feet 5 samples			19-21 Feet 6 samples			26-29 Feet 4 samples			33-35 Feet 2 samples			39 Feet 2 samples		
	Number	Volume		Number	Volume		Number	Volume		Number	Volume		Number	Volume		Number	Volume		Number	Volume	
	per square foot	ml. per square foot	percent of total at this depth	per square foot	ml. per square foot	percent of total at this depth	per square foot	ml. per square foot	percent of total at this depth	per square foot	ml. per square foot	percent of total at this depth	per square foot	ml. per square foot	percent of total at this depth	per square foot	ml. per square foot	percent of total at this depth	per square foot	ml. per square foot	percent of total at this depth
Oligochaeta	7	0.02	1.3	23	0.15	22.4	3	0.01	1.5	4	0.05	3.9	*	Tr.	Tr.	..	..	..	..	..	..
Tubificidae	*	Tr.	Tr.	6	0.02	3.0	..	..	..	*	Tr.	Tr.	*	Tr.	Tr.	..	..	..	..	..	..
Lumbriculidae (<u>Eclipidrilis</u> <u>sp.</u>)	7	0.02	1.3	17	0.13	19.4	3	0.01	1.5	4	0.05	3.9	..	..	..	..	..	..	..	..	..
Mollusca (<u>Pisidium</u> <u>sp.</u>)	77	0.11	7.4	114	0.17	25.3	270	0.60	77.4	340	0.70	55.5	*	Tr.	Tr.	..	..	..	..	..	..
Odonata	4	1.27	85.8	6	0.07	10.4	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Libellulidae	*	Tr.	Tr.	6	0.07	10.4	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Gomphidae	4	1.27	85.8	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Megaloptera (<u>Sialis</u> <u>sp.</u>)	2	0.01	0.9	8	0.20	29.8	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Tricoptera	2	Tr.	Tr.	3	0.01	1.5	..	..	..	3	0.01	0.8	..	..	..	..	..	..	..	..	..
Psychomyiidae	2	Tr.	Tr.	3	0.01	1.5	..	..	..	3	0.01	0.8	..	..	..	..	..	..	..	..	..
Leptoceridae (<u>Oecetis</u> sp.)	..	..	..	..	..	..	..	..	..	*	Tr.	Tr.	..	..	..	..	..	..	..	..	..
Diptera	105	0.07	4.2	91	0.07	10.4	40	0.14	18.1	57	0.50	39.2	101	0.61	96.6	122	0.47	100	28	0.06	100
Culicidae (<u>Chaoborus</u> sp.)	..	..	..	..	..	..	..	..	..	..	..	..	65	0.13	21.2	104	0.21	45.0	26	0.05	87.0
Heleidae	11	0.01	0.9	12	0.01	1.5	*	Tr.	Tr.	3	Tr.	Tr.	3	Tr.	Tr.	..	..	..	..	..	..
Tendipedidae	94	0.06	3.3	79	0.06	8.9	40	0.14	18.1	54	0.50	39.2	33	0.48	75.4	18	0.26	55.0	2	0.01	13.0
<u>Tendipes</u> <u>plumosus</u>	..	..	..	..	..	..	4	0.10	12.9	20	0.40	31.4	22	0.44	72.3	14	0.24	51.5	2	0.01	13.0
<u>Tendipes</u> <u>sp.</u> (Limnochironomus)	..	..	..	..	..	..	..	..	..	..	..	..	3	Tr.	Tr.	..	..	..	..	..	..
<u>Calopsetra</u> sp.	3	Tr.	Tr.	5	Tr.	Tr.	6	Tr.	Tr.	7	Tr.	Tr.	2	Tr.	Tr.	..	..	..	..	..	..
<u>Tanytarsus</u> sp. (Endochironomus)	..	..	..	..	..	..	..	..	..	1	Tr.	Tr.	2	Tr.	Tr.	..	..	..	..	..	..
<u>Tanytarsus</u> sp. J. Joh.	61	0.03	2.0	45	0.04	5.9	6	0.01	1.3	11	0.02	1.9	..	..	..	..	..	..	..	..	..
<u>Polypedilum</u> sp.	25	0.02	1.3	25	0.02	3.0	17	0.02	2.6	..	..	..	..	..	..	..	..	..	..	..	..
<u>Procladius</u> sp.	..	..	..	..	..	..	4	0.01	1.3	12	0.06	4.5	4	0.02	3.3	4	0.02	3.5	..	..	..
<u>Pentaneura</u> sp.	..	..	..	..	..	..	*	Tr.	Tr.	..	..	..	*	Tr.	Tr.	..	..	..	..	..	..
<u>Unidentified</u> larvae and pupae	5	0.01	0.4	4	Tr.	Tr.	3	Tr.	Tr.	4	0.02	1.4	..	..	..	..	..	..	..	..	..
Totals	197	1.48	99.6	245	0.67	99.8	313	0.776	97.0	404	1.26	99.4	101	0.61	96.6	122	0.47	100	28	0.06	100

* Less than 1.0 per square foot
Tr. = Volume less than 0.01 ml. and less than 0.1 percent

ANALYSIS OF FISH STOMACH CONTENTS

Analysis of the contents of stomachs of 25 brook trout collected by angling on August 16 and 18, 1952 is given in Table 5. Aquatic insects made up 87.1 percent by volume of the total food. Midge larvae were predominant. A single species of midge (Tendipes plumosus) made up 63.4 percent of all food. The fry of a centrarchid fish (probably bluegill) occurred in 2 stomachs, and an adult terrestrial insect occurred in one stomach. The organism most abundant in bottom fauna collections (the fingernail clam Pisidium) occurred in only 2 stomachs. The organisms identified in stomach contents were chiefly species living in the deeper water. The four food items comprising the greatest volume occurred in bottom samples collected between 10 and 39 feet. Larvae of the alder fly Sialis and dragonfly nymphs, which together made up a large portion of the bottom fauna of the 1- to 10-foot zone, were not found in stomachs. Thus it appears that trout were feeding principally in the deeper, cooler waters. A concentration of bottom fauna was to be found in the deep water (19 to 21 feet). None of the stomachs contained plankton. Plankton forms were probably too scarce to be effectively utilized by fish.

FISH

Between 1934 and 1941, several plantings of bluegills, perch and smallmouth bass were made in the lake. Brook trout of legal length were planted in 1934 and 1945. In October, 1946, 15,000 fin-clipped fingerling brook trout were planted. Growth of these fish was poor. A sample of 20 fish collected by Walter Crowe, district fisheries biologist, 20 months after stocking, averaged 6.03 inches in length and 1.06 ounces in weight. None of the fish was of legal length. In

Table 5.--Food of 25 brook trout collected by angling on August 16 and 18, 1952. One additional stomach was empty.

Food item	Depth of occurrence in bottom samples of food item	Percentage of stomachs containing food item	Number of organisms in stomachs containing the organism		Percentage of total volume (calculated)[1]
			Maximum	Average	
Mollusca					
Pisidium sp.	1-30	8	3	2	trace
Aquatic insects	1-39	92	34	12.1	87.1
Culicidae	13-39	56	22	5.7	7.5
Chaoborus punctipennis (L)	13-39	56	22	5.7	7.5
Chaoborus punctipennis (P)	*	4	1	1	trace
Tendipedidae	1-39	88	32	9.0	79.6
Tendipes plumosus (L)	13-39	56	18	6.1	63.4
Tendipes plumosus (P)	*	16	2	1.2	3.0
Procladius sp.	10-33	48	9	3.9	11.9
Pentaneura sp.	13-29	4	1	1	trace
Calopsectra sp.	1-29	36	19	4.9	1.3
Unidentified	?	12	3	1.6	trace
Terrestrial insects					
Hymenoptera (I)	*	8	1	1	0.5
Fish					
Unidentified fry of centrarchid (probably bluegill)	*	12	3	1.6	11.4
Totals					99.0

[1] The average volume of intact specimens collected in bottom fauna was substituted for the volume of specimens from stomachs that were poorly preserved.

* Not collected in bottom fauna.

(L) larvae (P) pupae (I) imago

August, 1948 the lake was poisoned. At that time, in addition to trout, it contained large numbers of stunted perch and bluegills. Since no fish were captured in nettings made subsequent to poisoning, the entire fish population is believed to have been eliminated. A planting of 7,500 fingerling and 750 adult brook trout was made in October, 1948. In 1948, 15,000 fingerling brook trout and 1,000 legal-sized rainbow trout were stocked. Fall plantings of 15,000 fingerling brook trout were made in 1950 and 1951.

Excellent early season trout fishing has been reported since poisoning and restocking with trout. In midsummer, good catches were made by fishing with bait at depths of from 15 to 25 feet. A sample of 26 fish taken by anglers between August 15 and August 17, 1952 averaged 7.2 inches in length and ranged between 6.5 and 8.1 inches. Scale samples of 6 of these fish were obtained. These fish also averaged 7.2 inches in length and were all one-year-old fish (fingerlings) stocked in the fall of 1951). Recently, bluegills have become re-established. During August, 1952, bluegill fingerlings were observed frequently in the shoal areas. Mr. James Skinner, conservation officer at Wolverine, reported that adult bluegills had been taken by angling during the summer of 1952.

MANAGEMENT RECOMMENDATIONS

Because of its availability to the public and its excellent camping facilities, the lake is of considerable recreational value. Interest in the lake has grown during the past few years, due to the reports of good brook trout fishing. The removal of warm-water species seems to have increased the growth rate of brook trout. Fish stocked as 3-inch fingerlings in the fall now attain legal length during the following summer. Since the growth rate of trout planted as fingerlings increased following the removal of warm-water species, growth will very likely be retarded if bluegills become abundant. Re-poisoning of the lake will be necessary to that time.

Limnological data indicate that plankton production is poor; zooplankton forms, particularly entomostraca, are scarce in late summer, although moderately abundant in early June. Midge larvae, particularly the species occurring in the lower epilimnion and thermocline, appear to be the principal food organisms utilized in late summer. The low chemical fertility of the lake unquestionably limits production of food organisms. Some form of chemical treatment will be required if the carrying capacity of the lake for trout is to be substantially increased. Fertilization with inorganic fertilizer is not recommended because of the high concentration of iron found in the bottom water. Einsele (1936) has shown that phosphorus is precipitated by iron in the presence of oxygen, and is this immobilized. Mineral fertilizer proved ineffective in Weber and Nebish lakes, two northeastern Wisconsin lakes of similar alkalinity, fertilized by Juday (1942). Hasler and Einsele (1950) have suggested that iron may be immobilized by the addition of sulfate and the subsequent precipitation of iron as ferric sulfide. During summer stagnation, water below 33 feet contains hydrogen sulfide; the sulfide, however, does not precipitate iron at the pH range found in the bottom water of Weber Lake. Raising the pH of the bottom water would theoretically make possible the precipitation of iron and would thus prevent immobilization of phosphorus by iron. Addition of hydrated lime and limestone was shown to be effective in increasing the pH of the bottom water of Cather Lake, a small Wisconsin lake of the soft water type, by Hasler _et al_ (1951). This treatment also reduced the concentration of iron. Preliminary results of experiments conducted at Stoner Lake, Alger County, Michigan by R. C. Ball and T. F. Waters of Michigan State College have indicated that the treatment recommended by the Wisconsin Workers brings about only minor changes in pH. Until a more thorough study of this type of chemical treatment has been made, it cannot be recommended as a management procedure but might be attempted on an experimental basis.

LITERATURE CITED

American Public Health Association.

1946. Standard Methods for the Examination of Water and Sewage. Ninth Edition, xvii + 286. Am. Publ. Health Assn., New York.

Birge, E. A. and C. Juday.

1930. A Second Report on Solar Radiation and Inland Lakes. Trans. Wis. Acad. Sci., Arts and Letters, 25:285-335.

Broughton, W. A.

1941. The Geology, Ground Water and Lake Basin Seal of the Region South of the Muskellunge Moraine, Vilas County, Wisconsin. Trans. Wisc. Acad. Sci., Arts and Letters, 33:5-20.

Einsele, Wilhelm.

1936. Uber die Beziehungen des Eisenkreislaufs zum Phosphatkreislauf im Eutrophen See. Arch. f. Hydrobiol., 29:664-686.

Greenbank, John.

1945. Limnological Conditions in Ice-Covered Lakes, Especially as Related to Winter-Kill of Fish. Ecol. Mon., 15:343-392.

Hasler, A. D., O. M. Brynildson, and William T. Helm.

1951. Improving Conditions for Fish in Brown-Water Bog Lakes by Alkalization. Jour. Wildl. Manag., 15:347-352.

Hasler, A. D., and W. G. Einsele.

1948. Fertilization for increasing productivity of natural inland waters. Trans. No. Amer. Wildl. Conf., 13:527-552.

Juday, C., E. A. Birge and V. W. Meloche.

1935. The Carbon Dioxide and Hydrogen Ion Content of the Lake Waters of Northeastern Wisconsin. Trans. Wis. Acad. Sci., Arts and Letters, 29:1-82.

Ohle, Waldemar.

1934. Chemische und physikalische Untersuchungen norddeutscher Seen. Archiv. f. Hydrobiol., 26:386-464 and 584-658.

Ruttner, Franz.

1953. Fundamentals of Limnology. English translation by D. G. Frey and F. E. J. Fry. Univ. Toronto Press, xi + 242. (Original German editiom published by Walter de Gruyter and Co., Berlin, 1952.)

Welch, Paul S.

1938. A Limnological Study of a Retrograding Bog Lake. Ecology, 19:435-453.

Wiebe, A. H.

1939. Density Currents in Norris Reservoir. Ecology, 20:446-450.

Yoshimura, S.

1932. On the Dichotomous Stratification of Hydrogen Ion Concentration in Some Japanese Lake Waters. Jap. Jour. Geol. and Geog., 9:155-185.

INSTITUTE FOR FISHERIES RESEARCH

Frank F. Hooper

Approved by: A. S. Hazzard

Typed by: Nancy Greenman