Proceedings of the Iowa Academy of Science

Volume 73 | Annual Issue Article 55

1966

Physico - Chemical Measurements of Miller's Bay, Lake West Okoboji, Summer, 1964

G. Dennis Cooke
University of Iowa

Physico — Chemical Measurements of Miller's Bay, Lake West Okoboji, Summer, 1964

G. Dennis Cooke[1]

Abstract: The purpose of this paper is to report on some physico-chemical measurements of Miller's Bay, Lake West Okoboji, made during summer, 1964, and to compare these measurements to some similar lakes. Lake West Okoboji, a large glacial lake, is located in northwest Iowa near the Minnesota border. Miller's Bay is small and is subjected to soil and domestic drainage. Measurements were made in April and at intervals from June to September. Samples were from 1 and 3 meter depths; depth at the sampling site was 8 meters. Water of the bay was hard and due primarily to magnesium, a situation similar to Lake Mendota. The comparatively high alkalinity was due entirely to bicarbonate. Free CO2 ranged from zero to 8 mg./L. and pH from 8.55-8.81. Nitrate, phosphate, and silicate were usually high and apparently related to domestic and soil drainage. Values were similar to other lakes receiving heavy allocthonous contributions. Nitrate was high, indicating sewage contamination. Transparency ranged from 1.1 to 2.9 meters. Turbidity and transparency were related to plankton blooms, not to rainfall. Bay water was nearly isothermal all summer.

Although there have been many biological studies of Lake West Okoboji, very little has been published on the physico-chemical environment of the lake. This paper is a report on some physico-chemical measurements made on the water of Miller's Bay during summer, 1964, and a comparison of the results with some similar lakes. The chemical measurements are of the amounts of plant nutrients present at any one moment, and not of their rate of exchange between organisms and environment. These rates are critical in evaluating the nutrient richness of a lake; this paper is therefore only a preliminary study.

Lake West Okoboji, a glacial lake, is located in Dickinson County, Iowa, in the northwest section of the state, adjacent to the Minnesota state boundary. The position is (Hutchinson, 1957) latitude 43°27'N., 95°10'W; elevation is 424.5 meters. According to the terminology of Hutchinson (1957), the lake is a dimictic, second-class, eutrophic lake. Its length is 8.79 kilometers, greatest width 4.57 kilometers, and area 1535 hectares. Physical features have been discussed by Birge and Juday (1920).

Miller's Bay, the smallest of the major bays of the lake, is located on the west side. The bay is about 1.4 kilometers in length, 1.2 kilometers across the mouth (Stromsten, 1927), and has an area of 53.1 hectares (Jones, 1925). Projecting from the north side of the bay is a long sandspit, which separates the

Zoology Department, University of Iowa, Iowa City.
[1] Department of Biological Sciences, Kent State University, Kent, Ohio 44240

northwest corner into a shallow pond-like bay, Little Miller's Bay (Fig. 1). Miller's Bay is surrounded by relatively high bluffs, except for a marshy area on the north shore. Three kinds of soils are found on adjacent shores: Pierce loam (north), Pierce fine sandy loam (west and south), and Lamoure silty clay loam (sandspit area). These soil types are highly calcareous, have moderate supplies of total phosphorus, and large amounts of total nitrogen (Stevenson and Brown, 1924). On the west side, a small stream, which drains through a heavily wooded area, enters the bay. In years prior to 1964, this stream has been polluted with sewage. During wet seasons, water from the marshy area behind the sandpit flows into Little Miller's Bay. On the South shore, a small canal connects Miller's Bay to Emerson's Bay, a large deep bay at the south end of the lake.

Prior to the installation of a sewage line around the lake, septic tanks, located near the shore, were used to handle domestic wastes. In addition to the contribution from soil run-off, much plant nutrient probably enters the water from these tanks.

Miller's Bay is shallow (maximum depth 10 meters) and is usually isothermal in the summer. The nature of the bottom varies with depth; shallow water bottom materials are cobbles and pebbles, and this stratum grades into gravel, sand and fi-

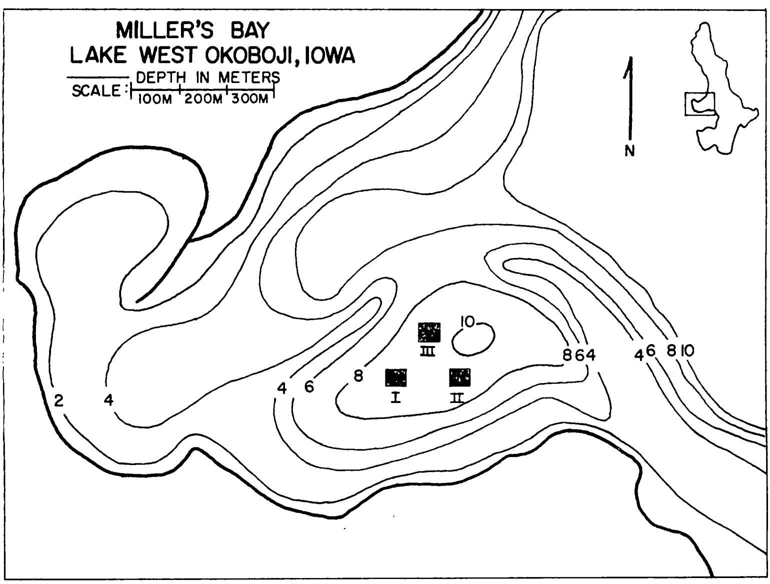

Fig. 1. Scale map of Miller's Bay, Lake West Okoboji, Iowa. Blocks indicate sampling area.

nally silt with increasing depth. Silt in deep water has an organic content of 25% (Clampitt et al., 1960).

Vascular plants are abundant near shore, particularly in the northwest corner adjacent to the shallow bay. The major producers in the open water are phytoplankton. During the summer, the phytoplankton is dominated by blooms of *Aphanizomenon, Gloeotrichia, Anabaena,* and *Microcystis.* The zooplankton of the bay is very similar to the deep, open-water of the lake. The same species of *Cyclops, Diaptomus,* and *Daphnia* are found in both areas of the lake (Cooke, 1963).

Methods

Water chemistry measurements of Miller's Bay were made on 6 April 1964, and at about weekly intervals from 23 June to 1 September 1964. All samples were taken within the area indicated by blocks in Figure 1, always at 1300 CDT, except in April when the sample was collected at 1500 CST. Depth at this site is 8 meters. On each sampling date, water for analysis was taken, using a 3 liter brass Kemmerer Bottle, from the upper one meter stratum and the stratum between two and three meters. Only a three meter sample was taken in April. Water was transported to the laboratory in one liter polyethylene-capped dark glass reagent bottles, which had been filled and allowed to overflow for 30 seconds. One sample was analyzed immediately (within 30 minutes) while the other was stored in the dark at 10°C until analysis of the first was completed.

A Hach DR-EL[2] water analysis apparatus was used. Procedures with this instrument are based on those in Standard Methods (APHA, 1960), and high accuracy is obtained within the sensitivity limits of the instrument. The reader is referred to Standard Methods or to Catalog Number 8 (Hach Chemical Company, Ames, Iowa) for details of procedure. Water temperature measurements were made with a Whitney Resistance Thermometer, and transparency was measured with a Secchi Disc.

Results and Discussions

Alkalinity, hardness, pH, free CO_2, nitrate, nitrite, phosphate, silicate, turbidity, transparency, and temperature were measured. Including both one and three meter samples, a total of 21 water chemistry measurements were made. Of these, 17 were below the accuracy limit (0.2 mg./L) for phosphate, 11 below the limit (0.005 mg./L) for nitrite, and 4 below the limit (0.2 mg./L) for nitrate. Values below the accuracy limits were estimated. The phosphate data is therefore least reliable. Water samples were not filtered prior to analysis. Values reported for nitrogen phosphorus, and silicate include those amounts found in the dissolved and possibly in the particulate fraction as well.

[2] Hach Chemical Company, Ames, Iowa

Results of this study are compared, where possible, with measurements on Lake Mendota, Wisconsin, a remarkably similar lake 500 miles due east of Lake Okoboji, with other Wisconsin lakes, and with Lake Erie.

A. *Alkalinity, hardness, pH, and free CO_2*

According to Reid (1961) a hardwater lake is one having a total hardness over 40 mg. $CaCO_3$/L, with low or no free CO_2, high bicarbonate alkalinity, little or no carbonate alkalinity, and a pH between 7.5 and 8.5. Such lakes have a high buffer capacity.

The water of Miller's Bay is hard (Fig. 2). Total hardness, which refers to the calcium and magnesium of water, was constant all summer, and values at one and three meters were nearly identical. The low value on 21 August was probably an error. Calcium hardness was always one-half or less than magnesium hardness, indicating that magnesium bicarbonate is the dominant buffer, a relationship similar to Lake Mendota (Birge and Juday, 1911). In most lakes, the magnesium fraction of alkaline carbonates is only 20% or less (Ruttner, 1963).

Free CO_2 measurements of Miller's Bay are questionable since changes may occur during transit of the sample, and the endpoint of the titration was not compared to a color standard. Free CO_2 of the bay varied from zero to 8.0 mg./L (Fig. 3), and was always higher at three meters depth.

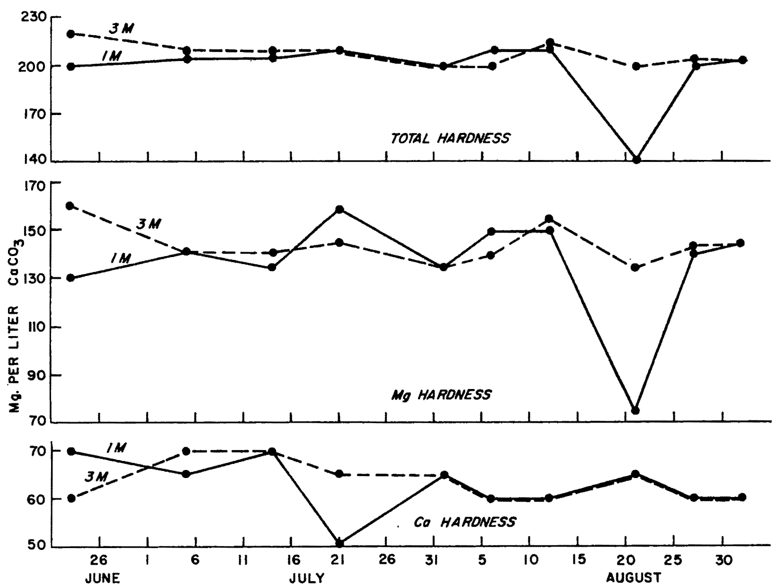

Fig. 2. Total, magnesium, and calcium hardness (mg. $CaCO_3$/L.) measurements of Miller's Bay, 1964.
———=1 meter depth. - - - - - =3 meter depth measurements.

Alkalinity was represented entirely by bicarbonate alkalinity (Fig. 3), and values were relatively constant through out the summer. The low reading at one meter on 23 June is probably an error. The range of alkalinity (90-240 mg. $CaCO_3$/L) is high in comparison to some other lakes, such as Lake Erie, where alka-

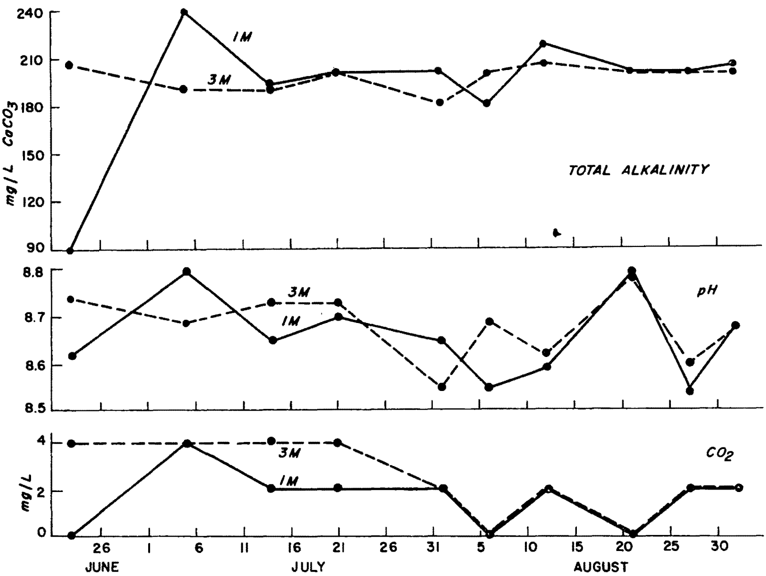

Fig. 3. Total (Bicarbonate) alkalinity (mg. $CaCO_3$/L.), pH, and free CO_2 measurements of Miller's Bay, 1964.
———— =1 meter depth, ... =3 meter depth measurements.

linity ranges from 100-120 mg. $CaCO_3$/L (Davis, 1958). This high bicarbonate alkalinity of the bay kept pH (Fig. 3) relatively constant throughout the summer (range 8.55-8.81).

B. *Nitrite and Nitrate*

Only extremely small quantities of nitrate and nitrite are usually found in lake waters during the summer. Domogalla et al., (1926) reported that in Lake Mendota, the annual nitrate maximum of 0.072 mg./L is reached in April, and during the summer it remains low, not exceeding 0.02 mg./L. In contrast, in Maumee Bay (Lake Erie), Verduin (1964) found that nitrate was very high (mean of 2.2 mg./L) and directly related to domestic and soil drainage. Nitrite values above 0.004 mg./L have been considered to be indicative of sewage contamination. Nitrite in Lake Mendota ranged from 0.018 mg./L in January to 0.006 mg./L in June (Domogalla et al., 1925).

Nitrate measurements at one meter depth in Miller's Bay varied from 0.7 on 23 June to an estimated 0.003 mg./L on 27 August, and at three meters varie from 0.6 mg./L on 1 August to undetectable on 27 August (Fig. 4). These low values on 27

August were associated with a bloom of the blue-green alga *Microcystis*. Heavy rain, accompanied by strong winds occurred on the evening of 27 August. On the following day, nitrate values were again high (0.4 mg./L). Rapid increases throughout the summer were usually preceded by heavy rain and strong winds. In April, 0.7 mg./L. nitrate was recorded. One meter nitrite in Miller's Bay varied from 0.006 to an estimated 0.002 mg./L., and three meter nitrite varied from 0.008 to an estimated 0.002 mg./L. (Fig. 4). In April, 0.007 mg./L. was found.

In contrast to Lake Mendota, a nitrate maximum was not found in the spring; highest values were in the summer. The amount of nitrate in Miller's Bay is more like that of Maumee Bay, and from the increases observed following wind and rain, it appears that the high amounts of nitrate in Miller's Bay are also due to rain-water and to run-off from the adjacent heavily fertilized farm lands. Amounts of nitrite in Miller's Bay are similar to those reported from Lake Mendota, but far higher than those reported for most other Wisconsin lakes. The high nitrite of the bay indicates sewage contamination.

It is important to point out that most published measurements of nitrogen in Wisconsin lakes were done at a time when the use of nitrogen-rich fertilizers was less than now. Also, it is probable that import of domestic sewage was much smaller at that time.

C. *Phosphate*

Soluble (ortho) phosphate is usually found in extremely small quantities in lakes. Juday and Birge (1931) reported that the mean quantity in 494 Wisconsin lakes was 0.003 mg./L. (surface). In lakes exposed to sewage and agricultural drainage, higher values are recorded. Sawyer (1946) found that average values of phosphate in five lakes (including Mendota) of the Yahara River Drainage ranged from 0.012 to 0.33 mg. PO_4/L., and Verduin (1964) reported that between 1950 and 1960 phosphate in Maumee Bay increased from a mean of 0.105 to a mean of 0.45 mg./L.

At one meter depth, phosphate in Miller's Bay ranged from 0.2 on 6 August to an estimated 0.05 mg./L. on 23 June, and at three meters ranged from 0.2 on 28 August to an estimated 0.03 mg./L. on 23 June (Fig. 4). In April, 0.05 mg./L. were found. In general, phosphate increased through the summer, and little difference between the two depths was noted. The high phosphate in Miller's Bay, similar in quantity to the lakes studies by Sawyer (1946) and Verduin (1964), is probably due to run-off from adjacent farms and to domestic drainage.

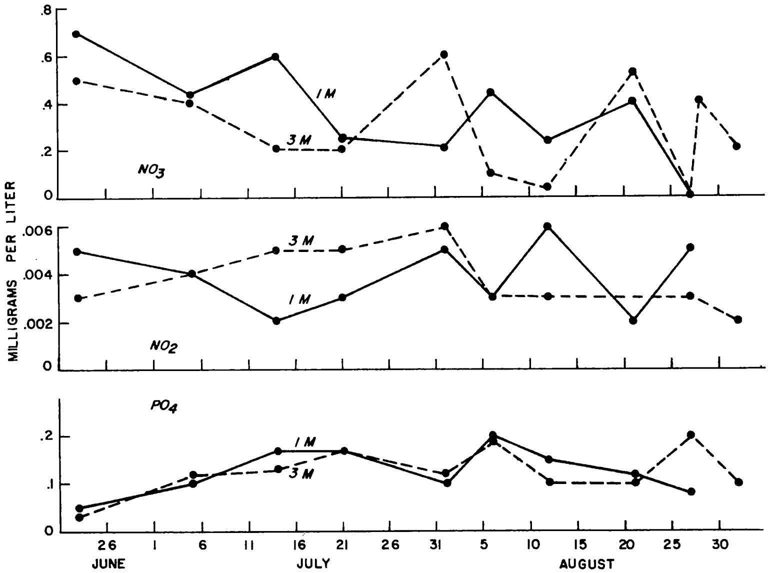

Fig. 4. Nitrate, nitrite, and phosphate (mg./L.) measurements of Miller's Bay, 1964.
———=1 meter depth, ...=3 meter depth measurements.

D. *Silica*

Silica in North America glacial lakes varies from about 0.05 to 26.0 mg./L. The silica cycle involves a steady increase through the summer to a high in fall and winter, a rapid decrease in spring during diatom blooms, then an increase in early summer (Hutchinson, 1957).

Silica determinations at one and three meters depth in Miller's Bay were nearly identical to each other on each sampling date (Fig. 5). Silica varied from a low of 0.58 on 6 April to a high of 4.6 mg./L. on 28 August, thus fitting the general pattern of steady silica increase during summer months. This range is wider than the range of 0.05 to 2.6 mg./L. reported for the epilimetic waters of Lake Mendota by Meloche et al. (1938). This difference may be due to the proximity of Miller's Bay to a large littoral area (Little Miller's Bay), continual circulation rather than stratification so that silica is not lost to bottom sediments, and to soil run-off.

E. *Water Temperature*

Studies of Miller's Bay in 1961 and 1962 (Cooke, 1963) as well as those of 1963 and 1964 show that during the summer, the bay is rarely stratified thermally, and variation from surface to bottom is usually less than two degrees centigrade, except during calm, hot periods when surface temperature may be several degrees higher than deeper strata. These isothermal conditions indicate that Miller's Bay is continually circulated.

The means of Miller's Bay water temperature determinations in the summers of 1963 and 1964 are plotted in Figure 5 in order to demonstrate the similarity of temperature changes during these two summers. A steady increase takes place in June through late July or early August. In August when most nights are cool and often windy, mean temperature decreases rapidly.

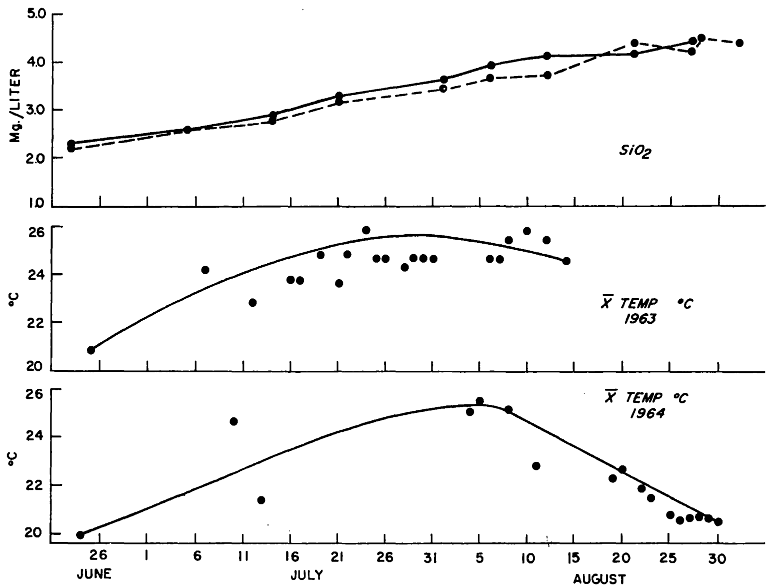

Fig. 5. Silica measurements (mg./L.) of Miller's Bay, 1964.
————=1 meter depth, ...=3 meter depth measurements.
Mean water temperature of Miller's Bay, 1963 and 1964, in degrees centigrade.

F. *Turbidity and Transparency*

Turbidity is the degree of opaqueness of water due to suspended particulate matter, and is responsible for scattering light. Turbidity was measured from thoroughly mixed water samples and results are expressed in Jackson Turbidity Units (JTU). A Secchi Disc, which measures depth of visibility, was used to estimate water transparency. There is a good association between transparency and transmission of solar radiation (Birge and Juday, 1929).

Secchi Disc readings in Miller's Bay (Fig. 6) ranged from 1.1 to 2.9 meters. Birge and Juday (1920) investigated the penetration of solar radiation of limnetic waters of Lake Okoboji during July, and found that 8.2% of the light striking the surface reached a depth of 2 meters; 4.4% reached a depth of 3 meters. Therefore, on the average, the Secchi Disc disappeared at a depth where

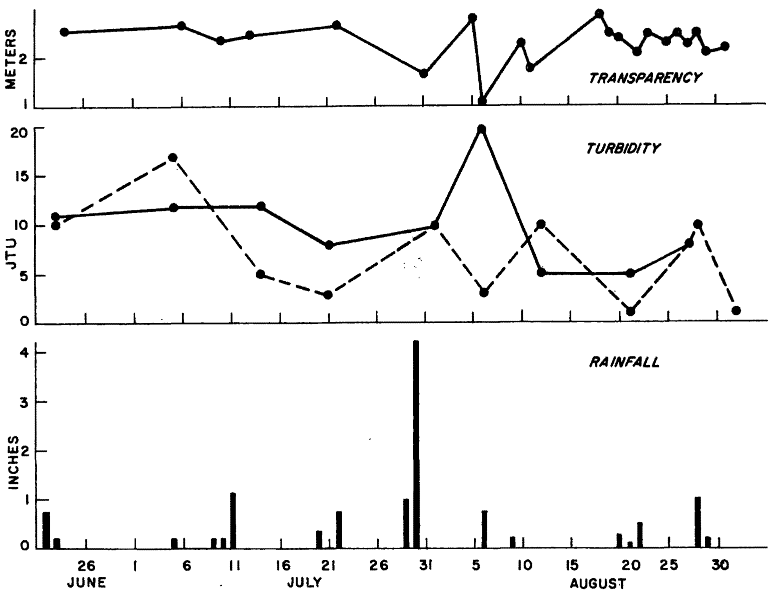

Fig. 6. Transparency (Secchi Disc depth in meters), turbidity (Jackson Turbidity Units), and rainfall (inches) measurements of Miller's Bay, 1964. ———— =1 meter depth, ... =3 meter depth measurements.

about 5% of surface light had penetrated. This is in good agreement with the calculations of Hutchinson (1957) on the relation between Secchi Disc readings and transmission of light.

Turbidity of the one meter stratum in Miller's Bay ranged from 5 to 22 JTU and was quite constant at 10 JTU from 23 June to 1 August (Fig. 6). Transparency during this interval was also constant. Turbidity of the three meter stratum ranged from 1 to 14 JTU, and was usually lower than one meter turbidity. In contrast to one meter values, turbidity of the three meter stratum fluctuated through the summer.

Chandler (1942) found that high turbidity was associated with high rainfall in Lake Erie. In Miller's Bay, changes in turbidity and transparency were not related to precipitation (Fig. 6). It was noted that during blooms of *Daphnia* in Miller's Bay, turbidity increased and transparency decreased, indicating that density of plankton organisms and associated organic debris may be very important in determining the amount of turbidity and light penetration.

Summary

Miller's Bay water is hard. Bicarbonate alkalinity is high and $Mg(HCO_3)_2$ is apparently the dominant buffer. The bay waters are rich in common plant nutrients (nitrates, phosphates, silicates) and this nutrient level is similar to other lakes exposed to

domestic and soil drainage. The water is apparently contaminated with sewage, as evidenced by high nitrites. Isothermal conditions exist through the summer, indicating continuous water circulation. On the average, Secchi Disc readings were at depths coincident with penetration of 5% of surface illumination. Both turbidity and transparency values were related to blooms of plankton, but not to rainfall.

The chemical environment of Miller's Bay is that of eutrophic water subjected to an allocthonous influence.

ACKNOWLEDGEMENTS

This manuscript was prepared while the author was a USPHS post-doctoral fellow (1-F2-WP-29, 492-01) at the Institute of Ecology, University of Georgia. Portions of the manuscript preparation were also supported by contract AF(38-1)-310 between the U.S. Atomic Energy Commission and the University of Georgia. I thank R. V. Bovbjerg, E. P. Odum, and R. J. Beyers for advice.

Literature Cited

American Public Health Association (APHA). 1960. 11th Ed., New York: The Association.
Birge, E. A. and Juday, C. 1911. Wisc. Geol. Nat. Hist. Surv., Bull., 22:1-259.
———. 1920. Univ. Iowa Stud. Nat. Hist. 9:1-56.
———. 1929. Trans. Wisc. Acad. Sci., 24:509-580.
Chandler, D. C. 1942. Ecol., 23:41-52.
Clampitt, P. T., Waffle, E. L. and Bovbjerg, R. V. 1960. Proc. Ia. Acad. Sci., 67:553-568.
Cooke, G. D. 1963. M. S. Thesis, University of Iowa.
Davis, C. C. 1958. Limnol. and Oceanogr., 3:15-28.
Domogalla, B. P., Juday, C., and Peterson, W. H. 1925. J. Biol. Chem., 63:269-285.
Domogalla, B. P., Fred, E. R., and Peterson, W. H. 1926. J. Amer. Wat. Wks. Assoc., 15:369-385.
Hutchinson, G. E. 1957. John Wiley and Sons, New York.
Jones, E. N. 1925. Proc. Ia. Acad. Sci., 32:181-188.
Juday, C. and Birge, E. A. 1931. Trans. Wisc. Acad. Sci., 26:353-382.
Meloche, V. W., Leader, G., Safranski, L., and Juday, C. 1938. Trans. Wisc. Acad. Sci., 31:363-376.
Reid, G. K. 1961. Reinhold Pub. Corp., New York.
Ruttner, F. 1963. 3rd. Ed. Univ. Toronto Press.
Sawyer, C. N. 1946. J. New Eng. Wat. Wks. Assoc., 61:109-127.
Stevenson, W. H. and Brown, P. E. 1924. Ia. Agric. Exp. Sta. Soil Surv., Iowa, Rept. No. 37.
Stromsten, F. A. 1927. Univ. Iowa Stud. Nat. Hist., 12:1-52.
Verduin, J. 1964. Verh, Int. Ver. Limnol., 15:639-644.