

LIMNOLOGICAL INVESTIGATIONS OF SOME TURBID
AND CLEAR FLINT HILLS FARM PONDS

by

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INTRODUCTION

In the past there were relatively few aquatic communities in Kansas, but this situation is now changing rapidly, because the number and diversity of man-made impoundments in this state are increasing every year. Many large reservoirs and lakes have been constructed for water supply, flood control, recreation, irrigation, and other purposes. In addition, approximately 100,000 farm ponds have been built throughout the state (Soil Conservation Service, 1974).

Most limnological studies have been conducted in large reservoirs, stratified clear lakes, rivers, and in the laboratory. Farm ponds provide a unique environment where physical, chemical, and biological characteristics are subject to rapid changes and wide variations. Just considering zooplankton alone, the species can differ greatly in their seasonal abundance; a single species may have different population curves in two adjacent bodies of water and from year to year in the same body of water (Pennak, 1953). The probability of there being fluctuations in zooplankton standing crops is governed by many factors, and one of the most important of these may be turbidity. Turbidity is a common feature in many farm ponds and its influences on pond ecology need more investigation in Kansas.

Most of the previous work done on farm ponds in Kansas was focused primarily on the general physico-chemical characteristics with minimal work done on the biological part. The most recent studies in this state did include zooplankton identification in addition to the physical and chemical variables. Little research has been published concerning

the characteristics and possible differences or similarities between farm ponds. The purpose of this study on Kansas Flint Hills farm ponds is to evaluate the presence of differences or similarities by classifying the six farm ponds according to their turbidity and drainage.

The primary objectives: 1) Determine the seasonal fluctuations of the selected physical, chemical, and biological variables in the three turbid and the three clear Flint Hills farm ponds. Turbid farm ponds were defined as having Secchi disc readings averaging less than one-half meter (greater than 50 JTU), and clear ponds were defined as having Secchi disc values which were more than one-half meter (less than 50 JTU); 2) Note any of the important differences between the clear and turbid farm ponds; 3) Describe the relationships between the variables being measured and their significance.

This thesis will consist of a review of the previous literature relating to the problem, a description of the study area, an abstract, a manuscript to be submitted for publication, and an appendix containing additional information on the modified method of particulate organic analysis, statistical results, and other supplementary data. The manuscript will contain a description of selected physical, chemical, and biological parameters and information on species composition and seasonal fluctuations of zooplankton in clear and turbid farm ponds.

LITERATURE REVIEW

Physical Properties

Physical determinations of various bodies of water are numerous and widespread. One of the most frequently studied parameters is water temperature. Tiemeier and Elder (1957), Tiemeier and Moorman (1957), and Tiemeier (1966) have all reported temperature conditions in Kansas Flint Hills farm ponds from May-October during the years 1955-1958. During this time surface temperatures ranged from 5.6°C . to 33.9°C ., and bottom temperatures ranged from 7.8°C . to 27.2°C . Thermal stratification was evident by late May, and destratification occurred during the middle of August. The maximum average difference between surface and bottom water temperatures was 11.1°C . Schultz (1952) and Hill *et al.* (1962) investigated Ohio farm ponds, and their results were similar to those found in Kansas by Tiemeier (1966). Schultz (1952) reported that inverse stratification existed from September until March. Wallen (1955) recorded an average surface temperature during July of 31.2°C . in Oklahoma ponds. The highest temperature recorded was 35.8°C . and the lowest 0.2°C . Wallen (1955) also noted that inverse stratification occurred even in the absence of ice cover. Stratification occurred in April and destratification occurred in late August (Wallen, 1955). Welch (1938) recorded a maximum July reading of 26.0°C . and a minimum April reading of 2.6°C . under ice in a Michigan bog pond. Ratzlaff (1952) noted a minimum temperature of 1.0°C . under ice in March and a maximum of 30.0°C . in June while investigating roadside ditches in Kansas. These findings are similar to those reported in Kansas (Leonard and

Ponder, 1949) and Colorado (Pennak, 1949). The maximum measurements recorded in Kansas (Tiemeier, 1966) and Oklahoma (Wallen, 1955) are five to seven degrees higher than those recorded from a Michigan bog pond by Welch (1938).

Turbidity is a limnological characteristic in many reservoirs, lakes, rivers, streams, and ponds. It is caused by suspended matter such as silt, clay, fine dispersions of organic matter, or planktonic organisms. Turbidity is an expression of the optical property of the liquid which causes light to be scattered and absorbed rather than transmitted in straight lines (American Public Health Association, 1965). Suspended particles can be so extensive that they reduce the penetration of light into the water, thus restricting phytoplankton primary production to near the surface (Ellis, 1936; Irwin, 1945; Ruttner, 1963). The reduction of the number of planktonic plants may decrease the amount of energy available to the higher trophic levels of the food chains within the aquatic community. Nonchlorophyll-bearing organisms are dependent to a large extent on the chlorophyll-bearing ones Welch, 1952).

Natural waters vary considerably in the amount of light they will absorb. Birge and Juday (1930) and Irwin and Stevenson (1951) found that light penetration was inversely related to turbidity and color. Irwin and Claffey (1968) demonstrated that light was able to penetrate waters with lower turbidities and permit the development of a photosynthetic zone at a greater depth. Wallen (1951a) and Butler (1962) investigated the relationship between turbidity and temperature in Oklahoma farm ponds and concluded that the bottom water temperatures were generally lower in turbid than in clear ponds and that thermal stratification was more pronounced in turbid ponds. Dissolved oxygen

in the Missouri River appeared to be inversely related to turbidity, and the biochemical oxygen demand of the suspended organics may be causing the low oxygen levels (Berner, 1951).

Buck (1956) found that high turbidities increased channel catfish production, but reduced reproductive success, growth, and total yield of bass and bluegills in Oklahoma ponds. Individual catfish grew faster in clear ponds, but muddy waters yielded greater total weights of channel catfish due to a higher survival rate. Wallen (1951b) has shown that lethal turbidities probably do not occur naturally for species of fish commonly stocked in farm ponds.

Tiemeier and Elder (1957) and Buck (1956) classified farm ponds according to their turbidity. Tiemeier and Elder (1957) classified ponds as clear if the average of summer turbidity readings was 40 ppm (parts per million) or less. Intermediate ponds had average turbidities between 41 and 100 ppm, while those over 100 ppm were designated as muddy. Buck (1956) categorized Oklahoma ponds as clear if the average turbidity was less than 25 ppm; those having average turbidities of 25 to 100 ppm were intermediate; and those ponds averaging more than 100 ppm were muddy.

Particulate organic matter content is a physical condition of natural waters that can be used as an index of the detrital matter available as food for zooplankton. Food is a vital part of the ecology of all organisms and reduced amounts may cause lower reproduction (Hall, 1964), slower growth rate (Richman, 1958), and in some cases starvation (Hutchinson, 1967).

Little has been published concerning the particulate organic matter in farm ponds. Wiebe (1930) was one of the first to measure

organic matter and this was done under controlled conditions in fertilized and unfertilized farm ponds. He noted that fertilized ponds have more organic matter than unfertilized ponds. Ratzlaff (1952) reported the organic seston concentrations in roadside ditches in Chase and Lyon counties and found an average of 19.9 mg/l (milligrams per liter). Pennak (1949) found an organic seston range from 5.4 mg/l to 828.7 mg/l. Prophet (1964) investigated the organic seston of Lyon County State Lake and reported a range of between 2.3 and 13.4 mg/l. Prophet (1957) also has determined the organic seston load of the Verdigris and Fall Rivers in Kansas. Organic seston ranged from 0.4 to 88.8 mg/l in the Verdigris and from 1.3 to 18.0 mg/l in the Fall River. Novak (1969) described the amount of particulate organic matter available in Tuttle Creek Reservoir at various times of the year and analyzed the relationship between particulate organic matter and other measured environmental variables. Taylor (1971) also measured particulate organic matter in Tuttle Creek Reservoir and determined the relationships of this and other parameters on zooplankton fluctuations. Novak (1969) and Taylor (1971) found that turbidity increased the particulate organics of the aquatic system. The increased particulates were subsequently reflected in the later primary productivity and secondary productivity.

Chemical Properties

Chemical analyses are important limnological indices of the condition of the water. Dissolved oxygen, carbon dioxide, hydrogen-ion concentration, and alkalinity are common water chemistry measurements, and many investigators have reported their findings: Andrews and Breukelman (1952) studied limnology in Kansas state lakes; Hill et al. (1962) investigated Ohio farm ponds; Prophet (1964) researched Lyon

County State Lake during reflooding; Ratzlaff (1952) worked on the limnology of roadside ditches in Chase and Lyon Counties, Kansas; Roach (1933) studies impounded waters in Ohio; Schultz (1952) made a limnological study of an Ohio farm pond; Surber and Olson (1936) worked on Minnesota fish ponds; Wallen (1955) investigated the limnology of Oklahoma farm ponds; Tiemeier and Elder (1957), Tiemeier and Moorman (1957), Willis (1959), Tiemeier (1966) and Smrchek (1970) have all studied the limnology of farm ponds in Kansas. Generally, dissolved oxygen values were high in the cooler months and lower during the warmer times of the year; concentrations in deeper water in the pond were less than those near the surface, especially during the summer months. Hydrogen-ion concentrations were mostly in the 6.5 to 8.5 range with some as low as 5.4 and as high as 10.6. The free carbon dioxide readings usually varied between 0.0 ppm and 15.0 ppm, with lower values near the surface of the pond and higher values near the bottom. Moore (1952) found values at the bottom of Louisiana lakes to be as high as 63.5 ppm. Most phenolphthalein alkalinities ranged between 0.0 and 10.0 ppm, with some values as high as 60.0 ppm. Methyl orange alkalinities ranged mostly between 50.0 and 150.0 ppm with some as great as 395 ppm.

Conductivity is a measure of a solution's ability to carry an electric current, or an estimate of the dissolved solids content (electrolyte concentration). Wallen (1955) measured the conductivity of Oklahoma ponds and reported average values of 12,000 to 22,000 milliams. Prophet (1964) recorded specific conductivities between 259 and 629 mmhos/cm (micromhos/centimeter) with a gradual increase from spring until fall in Lyon County State Lake. Prophet (1966) noted that specific conductivity in John Redmond reservoir in Kansas ranged from 300 to 758 mmhos/cm, and there also was a slight increase

from spring until fall. Smrchek (1970) found the range of conductivity (reciprocal megaohms) to be between 140 to 740 in eastern Kansas farm ponds, with the clear ponds having slightly greater values.

Ruttner (1963) reported that nitrates and phosphates occur in small quantities in lakes, and phytoplankton utilize both. In some instances phytoplankton even store phosphorus when there is an excess. Zeller (1953) investigated the roles of nitrogen and phosphorus in pond productivity, and concluded that the limiting factor was soluble phosphorus. Tiemeier (1966) noted low to very low concentrations of both nitrogen and phosphorus in Kansas pond soils. Surber and Olson (1936) reported ranges of 0.09 to 0.85 ppm for soluble phosphates in Minnesota farm ponds, and assessed the possibility of it being a limiting factor in plankton production. Nitrate nitrogen values varied from 0.08 to 4.50 ppm in Minnesota fish ponds (Surber and Olson, 1936). Wiebe (1930) found ranges for nitrate nitrogen between 0.01 and 0.12 ppm in unfertilized Wisconsin fish ponds. Hill et al. (1962) reported a range of 0.00 to 5.90 ppm nitrate nitrogen in fourteen Ohio farm ponds. Prophet (1964) found a range of 0.02 to 0.16 ppm for phosphates in Lyon County State Lake. John Redmond Reservoir had phosphate levels between 0.02 and 1.72 ppm and nitrate nitrogen levels between 0.00 and 1.40 ppm (Prophet, 1966). Smrchek (1970) found nitrate nitrogen levels fluctuated greatly, but there was a trend towards increasing nitrates from fall to winter and decreasing in the spring. Orthophosphate levels were low in March and high in April and May.

Swingle (1947) reported that enrichment of ponds with inorganic fertilizers increased the production of phytoplankton, and Bennett (1971) noted that phosphorus was the most important fertilizing element in lakes and ponds. Smith and Swingle (1938) found that fertilization

in ponds increased the production of plankton and more than doubled the production of bluegill.

Biological Properties

From the standpoint of nutrition physiology the plankton is composed of producers and consumers of organic matter (Ruttner, 1963). Every organism in the planktonic community is directly or indirectly dependent upon plant production. As previously mentioned many factors can effect phytoplankton productivity. Likewise, the amount of planktonic plants may influence the higher trophic levels of a pond.

No information has been published concerning chlorophyll concentrations in Kansas farm ponds. Prophet (1964) recorded values that ranged between 1.2 and 13.4 mg/m³ (milligrams per cubic meter) for Lyon County State Lake in Kansas. Lake Wooster had concentrations ranging between 12.0 and 40.0 mg/m³ (Prophet, 1964). Prophet (1966) reported chlorophyll-a concentrations to be lowest in the winter (less than 10 mg/m³) and highest in the summer (25 mg/m³) in John Redmond Reservoir. Tuttle Creek Reservoir had averages ranging from 7.67 to 16.70 mg/m³ (Taylor, 1971). Small (1963) reported chlorophyll-a in Clear Lake, Iowa, averaged approximately 45 mg/m³, and this was indicative of eutrophic conditions. Wright (1958) found chlorophyll concentrations in Canyon Ferry Reservoir, Montana, averaging 2.94 mg/m³. Goldman and Wetzel (1963) noted that maximum chlorophyll production occurred during the summer months and coincided with the period of maximum light intensity. The monthly mean concentration of chlorophyll varied inversely with phosphates and nitrates present in the euphotic zone (Prophet, 1966).

Zooplankton occur in many different types of aquatic habitats, and others are devoid of zooplankton. Environmental conditions

affect the density of each species and the composition of the community. Such factors as predation, food supply, and temperature act individually or collectively to control zooplankton populations (Fryer, 1957; Hall, 1964). The chemical components of the water may have an effect upon zooplankton in a few cases, but in most freshwater environments the effect is slight (Hutchinson, 1967).

Few studies concerning zooplankton life in ponds have been conducted in the United States outside of Kansas (Scott, 1910; Kreckler, 1919; Peterson, 1926; Wieve, 1930; Eddy, 1931; Surber and Olson, 1936; Ward, 1940; Kenk, 1949). Investigations in Kansas are even fewer in number. Smrcek (1970) and Willis (1959) have contributed the most recent biological pond studies. Leonard and Ponder (1949) made a checklist of crustaceans collected within a two and one-half mile radius of Lawrence, Kansas. Ratzlaff (1952) studied the limnology of some roadside ditches in Chase and Lyon counties, Kansas. Armitage (1961) recorded the species composition and seasonal distribution of limnetic crustacean zooplankton of northeastern Kansas. Prophet (1964) investigated the zooplankton of Lyon County State Lake during reflooding, while Koch and Wenke (1972) reported limnological information from Cedar Bluff Reservoir, Trego County, Kansas. Prophet, Andrews and Goulden (1959) compiled a checklist of cladocerans and copepods from Lyon County, Kansas, and later another checklist was published to include species from the entire state (Prophet and Waite, 1974). Prophet (1957) also reported seasonal variations and abundance of cladocerans and copepods in the Fall and Verdigris Rivers in Wilson and Montgomery counties, Kansas.

Pennak (1957) summarized the information concerning zooplankton literature and explained some of the complexity within the community.

Ahlstrom (1934) reported results on the community structure and seasonal fluctuations of rotifers in Terwilliger's Pond, Put-in-Bay, Ohio.

DESCRIPTION OF STUDY AREA

The present study was conducted on six farm ponds located in the Flint Hills grassland near Manhattan, Kansas (Figure 1). The three turbid ponds (T-1, T-2, T-3) and two of the three clear ponds (C-1, C-2) are located in Riley County; pond C-3 is located in Pottawatomie County. The exact locations for all of the ponds are as follows: T-1: R8E, T10S, NE $\frac{1}{4}$ Sec. 1 ; T-2: R8E, T10S, SW $\frac{1}{4}$ Sec.6; T-3: R7E, T9S, SE $\frac{1}{4}$ Sec. 20; C-1: R7E, T9S, NE $\frac{1}{4}$ Sec. 32; C-2: R7E, T9S, NW $\frac{1}{4}$ Sec. 33; C-3: R9E, T10S, NW $\frac{1}{4}$ Sec. 2.

The Flint Hills region, an important livestock grazing area extending from Nebraska to northern Oklahoma between the 96th and 97th meridians, is a strongly dissected plain with smooth, narrow divides bordered by rock outcrops and steep slopes (Anderson and Fly, 1955). The soils have developed from massive limestones, interbedded gray and yellow shales, and highly flinty or cherty limestones of the lower Permian formation (Fly, 1949). Anderson and Fly (1955) described the vegetation as true prairie dominated by little bluestem (Andropogon scoparius), sideoats grama (Bouteloua curtipendula), Kentucky bluegrass (Poa pratensis), big bluestem (Andropogon gerardi), Indiangrass (Sorghastrum nutans), and switchgrass (Panicum virgatum). The average annual temperature is 13.1° C. (55.6° F.) with averages ranging from -2.1° C. (28.7° F.) in January to 26.2° C. (79.1° F.) in July. The average annual precipitation is 85.14 cm (35.52 inches) with averages ranging from 2.18 cm (0.86 inches) in January to 14.83 cm (5.84 inches) occurring in June.

Most Flint Hills ponds are used primarily as a source of water for livestock, however, they do have potential for sport fishing and other recreation. The surface runoff type of pond receives a substantial amount of soil turbidity from April through July which prevents the growth of pondweeds and other macrophytes, yet allows the phytoplankton to grow and multiply in the euphotic zone. Others are relatively clear of turbidity, and this increased clarity enhances the growth of unfavorable pondweeds which entrap nutrients throughout the growing season. The clear ponds receive substantial amounts of spring flow which stabilizes the water levels near or over the full mark.

Most runoff occurs in the spring and early summer coinciding with the maximum period of precipitation, often causing turbidity levels to increase during this time. The area is subject to wide variations of temperature and precipitation during most of the year. High temperatures combined with lack of rainfall can cause water levels to decrease quite rapidly during the summertime. The springfed ponds are usually less affected by times of high evaporation, because the underground water flowing into the pond replenishes the water lost.

LITERATURE CITED

- Ahlstrom, E. H. 1934. A quantitative study of Rotatoria in Terwilliger's Pond, Put-in-Bay, Ohio. Bull. Ohio State Univ. Nat. Hist. Surv., vol. 6, pp. 1-36.
- American Public Health Association. 1965. Standard Methods for the Examination of Water and Wastewater, 12th ed. Amer. Pub. Health Assoc., Inc., New York. 769 p.
- Anderson, K. L. and C. L. Fly. 1955. Vegetation-soil relationships in Flint Hills bluestem pastures. J. Range Mgmt. 8(4): 163-169.
- Andrews, T. F. and J. Breukelman. 1952. Studies in Kansas limnology I. Survey of Kansas state lakes. Trans. Kan. Acad. Sci. 55: 315-329.
- Armitage, K. B. 1961. Species composition and seasonal distribution of limnetic crustacean zooplankton of northeastern Kansas. Trans. Kan. Acad. Sci. 64: 27-35.
- Bennett, G. W. 1971. Management of Lakes and Ponds. 2nd Edition. Van Nostrand Reinhold Co., New York. 375 p.
- Berner, L. M. 1951. Limnology of the lower Missouri River. Ecol. 32: 1-12.
- Birge, E. A. and C. Juday. 1930. A second report on solar radiation and inland lakes. Trans. Wisc. Acad. Sci. Arts and Lett. 25: 285-335.
- Buck, D. H. 1956. Effects of turbidity on fish and fishing. Okla. Fish. Res. Lab. Rept., No. 60, pp. 1-62.
- Butler, J. L. 1962. Temperature relations in shallow turbid ponds. Proc. Okla. Acad. Sci. 43: 90-95.
- Eddy, S. 1931. The plankton of some sink hole ponds in southern Illinois. State of Ill. Div. Nat. Hist. Surv. 19: 449-467.
- Ellis, M. M. 1936. Erosion silt as a factor in aquatic environments. Ecol. 17: 29-42.
- Fly, C. L. 1949. Agricultural resources areas of Kansas. Kansas State Board of Agr. Rept. 65(271): 126-195.
- Fryer, G. 1957. The food of some freshwater cyclopoid copepods and its ecological significance. J. Animal Ecol. 26: 263-286.

- Goldman, C. R. and R. G. Wetzel. 1963. A study of the primary productivity of Clear Lake, Lake County, California. *Ecol.* 44: 283-294.
- Hall, D. J. 1964. An experimental approach to the dynamics of a natural population of Daphnia galeata mendotae. *Ecol.* 45: 94-112.
- Hill, R. D., G. O. Schwab, G. W. Malaney, and H. H. Weiser. 1962. Quality of water in Ohio farm ponds. *Ohio Agr. Exp. Sta. Res. Bull.*, No. 922, pp. 1-66.
- Hutchinson, G. E. 1967. A treatise on limnology. Introduction to lake biology and the limnoplankton. John Wiley & Sons, Inc., New York. Vol. II: 1115 p.
- Irwin, W. H. 1945. Methods of precipitating colloidal soil particles from impounded waters of central Oklahoma. *Bull. Okla. A. & M. College*, No. 42, pp. 1-16.
- _____ and F. J. Claffey. 1968. Soil turbidity, light penetration and plankton populations in Oklahoma ponds and lakes. *Proc. Okla. Acad. Sci.* 47: 72-81.
- _____ and J. H. Stevenson. 1951. Physico-chemical nature of clay turbidity with special reference to clarification and productivity of impounded waters. *Bull. Okla. A. & M. College*, No. 48, pp. 1-54.
- Kenk, R. 1949. The animal life of temporary and permanent ponds in southern Michigan. *Misc. Publ. Mus. Zool. Univ. Mich.* 71: 1-66.
- Koch, D. L. and T. L. Wenke. 1972. Some limnological features of Cedar Bluff Reservoir, Trego County, Kansas. *Trans. Kan. Acad. Sci.* 75: 226-230.
- Krecker, F. H. 1919. The fauna of rock bottom ponds. *Ohio J. Sci.* 19: 427-474.
- Leonard, A. B. and L. H. Ponder. 1949. Crustacea in eastern Kansas. *Trans. Kan. Acad. Sci.* 52: 168-204.
- Moore, W. G. 1952. Limnological studies of Louisiana lakes. 2. Lake Chicot. *Proc. La. Acad. Sci.* 15: 37-49.
- Novak, M. A. 1969. Seasonal variation of particulate organic matter in Tuttle Creek Reservoir. Master's Thesis. Kansas State University. 42 p.
- Pennak, R. W. 1949. Annual limnological cycles in some Colorado reservoir lakes. *Ecol. Monogr.* 19(3): 233-267.
- _____ 1953. Freshwater Invertebrates of the United States. The Ronald Press Co., New York. 769 p.

- _____. 1957. Species composition of limnetic zooplankton communities. *Limnol. Oceanogr.* 2(3): 222-232.
- Peterson, W. 1926. Seasonal succession of animals in a chara-cattail pond. *Ecol.* 7: 371-377.
- Prophet, C. W. 1957. Seasonal variations and abundance of cladocera and copepoda and some physical-chemical conditions of the Fall and Verdigris rivers in Wilson and Montgomery counties, Kansas. *Emporia State Research Studies.* 5(3): 1-29.
- _____, T. F. Andrews, and C. E. Goulden. 1959. Annotated checklist of the cladocera and copepoda of Lyon County, Kansas. *Southwest. Nat.* 4(4): 185-194.
- _____. 1964. Some limnological features of Lyon County State Lake during reflooding. *Trans. Kan. Acad. Sci.* 67(4): 676-685.
- _____. 1966. Limnology of John Redmond Reservoir, Kansas *Emporia State Research Studies.* 15: 5- 27.
- _____ and S. Waite. 1974. A species list of cladocera and copepoda. *Trans. Kan. Acad. Sci.* 77(1): 42-47.
- Ratzlaff, W. 1952. The limnology of some roadside ditches in Chase and Lyon Counties, Kansas. *The Emporia State Research Studies.* 1(1): 5-32.
- Richman, S. 1958. The transformation of energy by Daphnia pulex. *Ecol. Monogr.* 28: 273-291.
- Roach, L. S. 1933. Some physical, chemical, and biological studies of impounded waters in Ohio. *Trans. Amer. Fish. Soc.* 63: 2 pp.
- Ruttner, F. 1963. *Fundamentals of Limnology.* 3rd Edition. University of Toronto Press, Canada. 295 p.
- Schultz, V. 1952. A limnological study of an Ohio farm pond. *Ohio J. Sci.* 52(5): 267-285.
- Scott, W. 1910. The fauna of a solution pond. *Proc. Ind. Acad. Sci.* 20: 395-442.
- Small, L. F. 1963. Effect of wind on the distribution of chlorophyll-a in Clear Lake, Iowa. *Limnol. and Oceanogr.* 8: 426-432.
- Smith, E. V. and H. S. Swingle. 1938. The relationship between plankton production and fish production in ponds. *Trans. Amer. Fish. Soc.* 68: 309-315.
- Smrchek, J. C. 1970. A limnological study of three farm ponds in Douglas County, Kansas. *Trans. Kan. Acad. Sci.* 73: 181-226.

- State Soil Conservation Committee. 1974. Conservation in Kansas. State Soil Conservation Committee Report No. 1971, pp. 1-16.
- Surber, T. and T. A. Olson. 1936. Some observations on Minnesota fish ponds. *Trans. Amer. Fish. Soc.* 66: 104-127.
- Swingle, H. S. 1947. Experiments on pond fertilization. *Ala. Poly. Inst. Agr. Expt. Sta. Bull.*, No. 264, pp. 1-34.
- Taylor, M. W. 1971. Zooplankton ecology of a Great Plains Reservoir. Master's Thesis. Kansas State University. 85 p.
- Tiemeier, O. W. and J. B. Elder. 1957. Limnology of Flint Hills farm ponds. *Trans. Kan. Acad. Sci.* 60: 379-392.
- _____ and R. B. Moorman. 1957. Limnological observations on some Flint Hills farm ponds. *Trans. Kan. Acad. Sci.* 60: 167-173.
- _____. 1966. Kansas farm ponds. *Kan. St. Univ. Agr. Exp. Sta. Bull.*, No. 488, pp. 1-64.
- Wallen, I. E. 1951a. The relationship of turbidity to temperature of some farm ponds. *Proc. Okla. Acad. Sci.* 32: 20-26.
- _____. 1951b. The direct effect of turbidity on fishes. *Bull. Okla. Agr. and Mech. Coll.* 48(2): 1-27.
- _____. 1955. Some limnological considerations in the productivity of Oklahoma farm ponds. *J. Wildl. Manag.* 19: 450-462.
- Ward, E. B. 1940. A seasonal population study of pond entomostraca in the Cincinnati region. *Amer. Midl. Nat.* 23: 635-691.
- Welch, P. S. 1938. A limnological study of a retrograding bog lake. *Ecol.* 19: 435-453.
- _____. 1952. *Limnology*. 2nd Edition. McGraw-Hill Book Co., New York. 538 p.
- Wiebe, A. H. 1930. Investigations on plankton production in fish ponds. *Bull. U. S. Bur. Fish. (Doc. 1082)* 46: 137-176.
- Willis, H. 1959. Some limnological conditions of Turkey Creek and two ponds near Shawnee, Kansas from June 8, 1957, to August 16, 1957. *Trans. Kan. Acad. Sci.* 62: 20-27.
- Wright, J. C. 1958. The limnology of Canyon Ferry Reservoir. I. Phytoplankton-zooplankton relationships in the euphotic zone during September and October, 1956. *Limnol. and Oceanogr.* 3: 150-159.
- Zeller, H. D. 1953. Nitrogen and phosphorus concentrations in fertilized and unfertilized farm ponds in central Missouri. *Trans. Amer. Fish. Soc.* 82: 281-288.

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ABSTRACT

The purposes of this study were to monitor and illustrate the levels of the selected physical, chemical, and biological characteristics of the three clear and three turbid Kansas Flint Hills farm ponds, note any of the important differences between the two pond types, and describe the relationships between the variables being measured and their significance. Each pond was investigated by sampling every two weeks from March, 1974 until October, 1974.

The turbid ponds had significantly greater average turbidity and lower water level below the outlet than the clear ponds, while temperatures did not differ between pond types. Particulate organic matter densities averaged nearly always higher in the turbid ponds, although neither of the two pond types had levels that were significantly different. Of the chemical characteristics, total alkalinity and hydrogen-ion concentrations were significantly higher in the clear ponds, while nitrate-nitrogen values were significantly greater in the turbid ponds. Free carbon dioxide and dissolved oxygen had concentrations that were not significantly different between the two pond types. Specific conductivities and orthophosphate levels were not significantly different in either the clear or the turbid ponds, but their averages showed that the conductivities were higher in the clear ponds, and the orthophosphate concentrations were greater in the turbid ponds.

Biological characteristics were analyzed, and it was found that chlorophyll-a concentrations averaged much higher in the turbid ponds, but the ponds were not significantly different. All zooplankton

genera occurring in the ponds were identified, and the densities of Filinia longiseta, Diaptomus sp., total zooplankton number, and zooplankton biomass were significantly greater in the turbid ponds. Keratella cochlearis, Asplanchna sp., Daphnia sp., Bosmina longirostris, Ceriodaphnia lacustris, Cyclops sp., and copepod nauplii were not statistically different in abundance in either one of the two types of ponds. Ceriodaphnia lacustris and Cyclops sp. had greater average population sizes in the turbid ponds, although there was no significant difference between pond types. Diaphanosoma brachyurum occurred only in two of the three turbid ponds, and Macrothrix laticornis occurred in only one of the turbid ponds.

LIMNOLOGICAL INVESTIGATIONS OF SOME TURBID

AND CLEAR FLINT HILLS FARM PONDS

INTRODUCTION

Farm ponds have become a common aquatic ecosystem in Kansas. Their physical, chemical and biological characteristics vary greatly and their interrelations are not fully understood. Most studies concerning limnology have been conducted in large reservoirs, stratified clear lakes, rivers, and in the laboratory, but little research has been published concerning the characteristics and possible differences or similarities between farm ponds and in particular between clear and turbid farm ponds. Kansas farm ponds have received some limnological attention (Tiemeier and Elder, 1957; Tiemeier and Moorman, 1957; Tiemeier, 1966 ; these being focused primarily on general physico-chemical characteristics and some of their effects upon fish and fish production. The most recent investigations of Kansas farm ponds were concentrated on zooplankton in addition to physical and chemical variables (Willis, 1959; Smrcek, 1970). Since turbidity is a common feature of many Kansas ponds; more investigations are needed to determine the relationship of turbidity to other factors.

The primary objectives of this study were: 1) Determine the seasonal fluctuations of the selected physical, chemical, and biological variables in the three turbid and the three clear Flint Hills farm ponds. Turbid farm ponds were defined as having Secchi disc readings averaging less than one-half meter (greater than 50 JTU), and clear ponds were defined as having Secchi disc values which were more than one-half meter (less than 50 JTU); 2) Note any of the important differences between

the clear and turbid farm ponds; 3) Describe the relationships between the variables being measured and their significance.

MATERIALS AND METHODS

The study was conducted on six farm ponds of varying size and nature, located within the Kansas River drainage in Pottawatomie and Riley Counties, Kansas (Figure 1). The ponds were classified according to light penetration measured with a six-inch Secchi disc and according to turbidometric readings (JTU's). Three ponds were rated as clear with an average Secchi disc reading of 82.0 cm. (26 JTU's) and a range of 35. to 220. cm.; three were rated as turbid with an average reading of 28.4 cm. (132. JTU's) and a range of 10 to 90 cm. Water entered the turbid ponds by surface runoff, while the clear ponds received water from surface runoff and springflow. Clear ponds supported substantial amounts of macrophytes while the turbid ponds had little or no plants of this type. Tables 1 and 2 give additional characteristics concerning the farm ponds.

The ponds were mapped according to the stadia survey method described by Welch (1948). Sampling was conducted at biweekly intervals in the deeper part of the pond. Samples for physical, chemical, and biological analyses were taken at the surface and bottom with a modified Van Dorn type bottle. Transparencies were determined with a six inch Secchi disc and temperatures were taken at one-half meter intervals with an Spplied Research Associates FT3 hydrographic themometer. Turbidities were measured in Jackson Turbidity Units using the Hach colorimeter. Particulate organic matter in milligrams of carbon per cubic meter (mgC/m^3) was determined using the spectrophotometric method presented by Strickland and Parsons (1960) and modified by Taylor (1971) (Appendix I).

Specific conductivity was measured in micromhos per cm (mmhos/cm) with a model 2300 Hach Dissolved Solids Meter. Dissolved oxygen concentrations in parts per million (ppm) were determined by the Hach method. Hydrogen-ion concentrations were measured according to the Hach colorimetric procedure using the Hach AC-DR colorimeter. The Hach cadmium reduction method was used to determine the nitrate-nitrogen levels, while orthophosphate concentrations were measured according to the Hach stannous chloride method. Total alkalinities (ppm as CaCO_3) and free carbon dioxide were determined according to the Hach method.

The spectrophotometric method of Richards and Thompson (1952) was used to extract the chlorophyll from the water samples. The revised equations discussed by Parsons and Strickland (1963) were utilized in the determination of chlorophyll-a concentrations in milligrams per cubic meter (mg/m^3). All spectrophotometric methods used a Beckman model DB-GT, 115 volt, 60 hertz spectrophotometer.

Zooplankton were collected by taking five vertical tows (samples) with a Wisconsin #20 plankton net (mesh size = 0.07 mm) from an area near the deepest part of the pond. Each sample was kept separate, and the organisms were killed and preserved in 10 % formalin solution. Three of the samples were used for differential zooplankton counts. A rotary type counting cell was employed for determination of relative abundance (Ward, 1955). The number of individuals of each species per liter was calculated on the basis of the average number in three, one ml. subsample counts taken from each sample. Keys by Pennak (1953) and Edmondson (1959) facilitated identification. The other two samples were kept undisturbed for later reference.

Figure 1. Map showing the location of the turbid (T) and the clear (C) ponds in Riley and Pottawatomie Counties, Kansas.

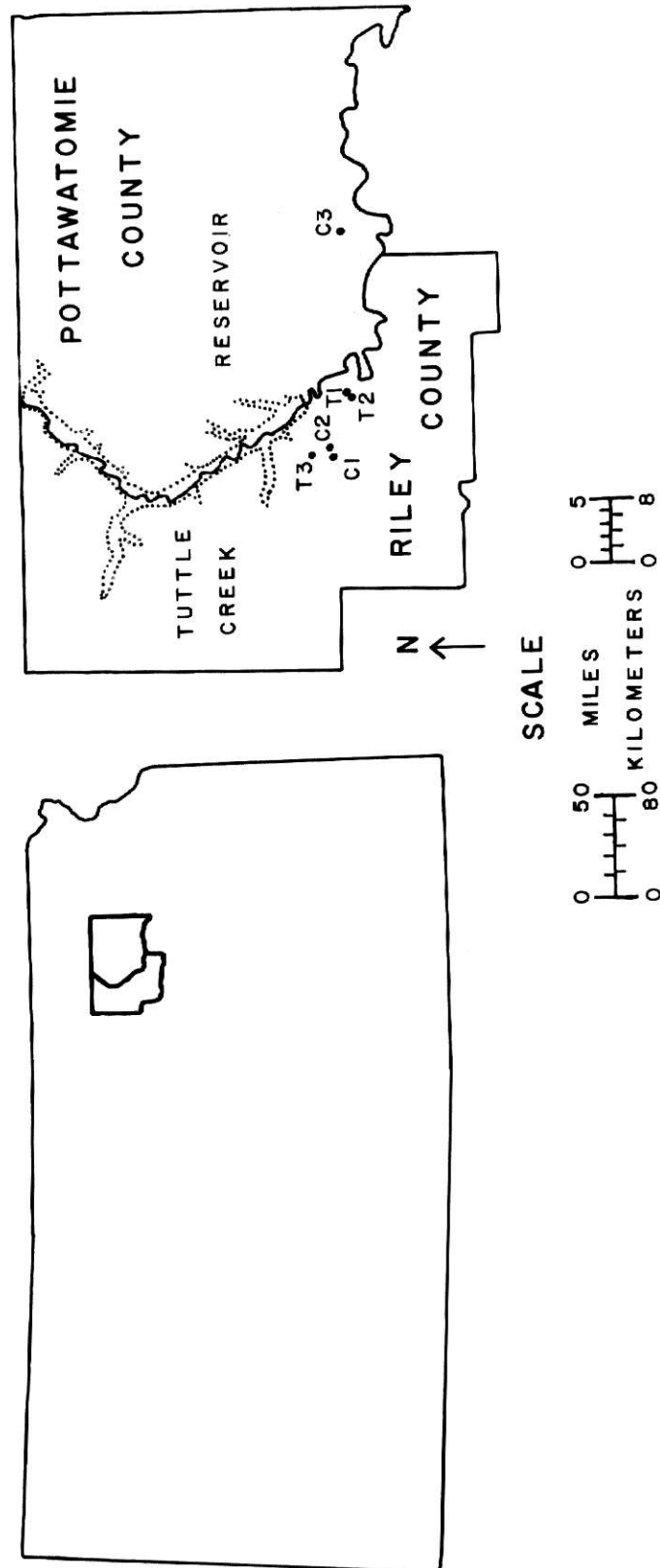


Figure 1

After the zooplankton had been counted, the three samples were combined for use in the biomass determinations. The mixture was filtered onto an oven dried, previously weighed circular piece of # 20 bolting cloth and allowed to dry at 50° C. for 24 hours. The dried filter and zooplankton were weighed to the nearest 0.1 milligram, and the net weight of the zooplankton calculated.

Fish occurred in each of the ponds, but their effect was not determined. Ponds T-1, T-3, and C-1 contained only bluegill (Lepomis macrochirus). Pond T-2 had black bullhead (Ictalurus melas) and bluegill while pond C-2 had largemouth bass (Micropterus salmoides), green sunfish (Lepomis cyanellus), and bluegill. Pond C-3 contained largemouth bass, bluegill, and channel catfish.

Three-way analysis of variance was used to detect the difference between selected variables due to pond types, date, and the effect of the type-date interaction (Appendix II). The lowest degree of significance accepted was 0.20, due to the inherent variability of these kinds of data. The mean square for ponds in the analysis of variance table was used as the denominator for calculating the "F" statistic for pond type. Each plot in the figures represents the mean of three observations.

RESULTS

Physical

The morphometric data for the six ponds are presented in Table 1, and the mean values for other selected physical, chemical, and biological variables are given in Table 2. There was a significant in the water level patterns between the clear and the turbid ponds (Figure 2). Clear ponds remained nearer to their maximum area, maximum volume, and maximum depth than did the turbid ponds. Most of the time water was flowing

out of the clear ponds; this was due largely to the underground springflow into the ponds. Turbid ponds had lower water levels which fluctuated in the spring during times of maximum precipitation and dropped during summer and fall. The water level patterns for the turbid ponds reflected the precipitation received. During the spring rain fell in substantial amounts to allow runoff into the ponds keeping the water levels near their outlets. Summer precipitation was not great, and a dry spell continued until the fall of the year. No observable springflow was ever noted for the turbid ponds during the study.

Turbidities for both types of ponds were quite divergent throughout the year (Figure 3). Turbid ponds increased greatly in turbidity during the spring of the year coinciding with maximum rainfall and runoff conditions. Following this, turbidities decreased gradually until an average of approximately 100 JTU's was reached. Surface water turbidities for the clear ponds did not fluctuate as those of the turbid ponds, but remained within the 10-50 JTU range. Even during times of high runoff, the surface water did not show appreciable increases in turbidity. Bottom water in the clear ponds showed more variation than did the surface water; this was due largely to the increase susceptibility of Pond C-3 to clouding during periods of increased runoff (Figure 3; Table 2). The other two clear ponds retained low turbidities during this time.

Neither the surface nor the bottom water temperatures were significantly different between the two pond types (Figure 4), and the temperatures for all of the ponds followed the same trend over time. Mean surface water temperatures increased steadily from a low of 3° C. in March to a high of 29° C. in late July and early August,

while bottom temperatures ranged from 3° C. to 22.5° C. The maximum average difference between surface and bottom water was 7° C. in late July. Surface and bottom water temperatures were nearly equal (homothermal) in mid-March and again in mid-October.

Particulate organic matter data from the turbid ponds shows concentrations to be quite high in the spring and a fluctuating but gradual increase in the summer and fall (Figure 5). In early June and mid-July the average particulate organics for the turbid ponds dropped below that for the clear ponds. The average of the surface and bottom water for the turbid ponds was approximately twice that of the clear ponds, but there was no significant difference between the two pond types. Pond T-2 had a high organic content throughout the year due to some extent to the agricultural drainage into the pond. Clear ponds had low particulate organics in the spring, and a gradual increase until mid- to late summer (Figure 5). Following these maxima the particulate organics decreased to a level slightly above that which occurred in the early spring. Turbid and clear pond particulate organic concentrations showed a very close resemblance to the chlorophyll-a densities (Figure 13). The fluctuations in chlorophyll-a appeared to be reflected in the particulate organic analysis (correlation coefficient = 0.85).

Chemical Analysis

Phenolphthalein alkalinities did not appear until late in the sampling period; therefore, only total alkalinity was analyzed. The average total alkalinity for the surface and bottom water from the turbid ponds was significantly lower than that occurring in the clear ponds (Figure 6). Fluctuations occurred throughout the year, but

both pond types had lower alkalinity in the spring, increasing to a maximum in mid-July; then decreasing slightly in the fall. Pond C-3 had a lower alkalinity than the other two clear ponds (Table 2), more near to that of the turbid ponds. Total alkalinity was usually somewhat higher in the bottom water.

Specific conductivities for surface and bottom water for turbid and clear ponds appear in Figure 7. The pond types had conductivities which were quite divergent but not significantly different; the clear ponds having the greater average. Conductivities for the clear ponds ranged between 310-430 mmhos/cm, while the turbid ponds ranged between 190-310 mmhos/cm. Both types of ponds had similar fluctuations to those displayed by the total alkalinity analysis. The relationship between alkalinity and conductivity is a linear one where increasing total alkalinity coincides with increasing conductivity. The present analysis reflected this close relationship (correlation coefficient = 0.92). As in the alkalinity determinations Pond C-3 again had a lower level of specific conductivity which was more near that of the turbid ponds.

Hydrogen-ion concentrations for surface water fluctuated but gradually increased from early spring until the fall, while bottom water concentrations decreased gradually until early August, then increased the remaining part of the year (Figure 8). Surface water hydrogen-ion concentrations for the clear ponds were significantly greater than those for the turbid ponds. There was no significant difference between bottom water values in either of the two types of ponds. The hydrogen-ion levels were inversely related to the free carbon dioxide in the water (correlation coefficient = 0.88) and positively related to both total alkalinity and specific conductivity. Surface water consistently had greater pH values than did the bottom.

Free carbon dioxide levels for surface and bottom water in both types of ponds are displayed in Figure 9. The turbid ponds had higher carbon dioxide levels in the early part of the year, decreasing steadily until October. The clear ponds increased from a low of 1.5 ppm in March to a high in mid-June. The carbon Dioxide decreased in the clear ponds until there was none on the surface and 1.0 ppm near the bottom. There were no significant differences between types of ponds, even though the means differed; the turbid ponds had the greater mean carbon dioxide level. Bottom water usually had more free carbon dioxide than the surface water in all of the ponds sampled. As was discussed previously the carbon dioxide levels were inversely related to the hydrogen-ion concentrations; and higher carbon dioxide concentrations were nearly always associated with lower oxygen levels (correlation coefficient = -0.80).

Dissolved oxygen values for the two types of ponds did not differ significantly throughout the sampling period (Figure 10). Dissolved oxygen in the surface water declined from a high of 12.0 ppm to a low of 5.6 ppm, while bottom water values decreased from 12.0 ppm to 0.8 ppm. By October the bottom water concentrations were equal to those of the surface. Increased water temperatures in the spring lowered the saturation value for oxygen and increased the respiration rate, thus leading to declining oxygen levels. Bottom water oxygen concentrations decreased the most because there was no replenishment from surface aeration and consumption exceeded production.

Nitrate-nitrogen concentrations for all ponds were greater in the spring after the ice had disappeared, and turnover was at its maximum (Figure 11). Concentrations decreased rapidly in June to levels

that stayed relatively the same the rest of the year. Utilization of the nitrates by the phytoplankton and other aquatic plants may have caused the decline of the nutrient salts. Chlorophyll concentrations increased (Figure 13) at the same time nitrates decreased. Nitrate-nitrogen levels were lower at the surface than at the bottom, and average concentrations appeared to be significantly greater in turbid pond bottom water than in clear pond bottom waters (Table 2). However, no significant difference was observed between turbid and clear surface water concentrations.

Orthophosphate concentrations averaged much greater in the springtime than at other times of the year, especially in the turbid ponds (Figure 12). Clear ponds had relatively low springtime levels that decreased to less than 0.04 ppm at the end of the the sampling period. Turbid ponds never did decrease to the low average levels of the clear ponds. Maximum utilization by plants also coincided with decreased orthophosphate concentrations, and the levels of this nutrient were usually greater near the bottom than at the surface (Table 2).

Chlorophyll-a concentrations were indicative of the amount of phytoplankton existing in the aquatic community. Increases were most notable in both pond types after the middle of June (Figure 13), coinciding with the greatest decrease in nutrient salts (Figures 11, 12) and with water temperature (Figure 4) increases. Greater mean concentrations were evident in the turbid ponds than in the clear ponds. Chlorophyll-a levels in the turbid ponds were usually greater nearer the surface than at the bottom, while the reverse was true in clear ponds (Table 2). Much of the chlorophyll during the earlier times of the year was due to phytoplanktonic green algae such as Pandorina, Chrysococcus, Trachelomonas, Pteromonas, and Chlamydomonas.

Zooplankton Analysis

The mean values for each zooplankton species, for total zooplankton, and for zooplankton biomass occurring in the three turbid (T) and the three clear (C) farm ponds are shown in Table 3.

Three species of rotifers were commonly found in the six ponds (Figure 14; Table 3). They were Filinia longiseta, Asplanchna sp., and Keratella cochlearis. Keratella quadrata and Brachionus sp. were also found but occurred infrequently throughout the sampling period and in low numbers. Filinia longiseta occurred in significantly greater numbers in the turbid ponds. Neither of the two types of ponds were affected the same by the time of the year. The turbid ponds had large populations in March and again in October with two smaller increases in June and in August. Clear pond densities stayed at low levels for the first six months of the sampling period, then increased slightly in August. In late September and early October the populations decreased to their previous low levels.

Asplanchna sp. was the second of the three species of rotifers to occur in the farm ponds (Figure 14). Neither type of pond had a significantly greater population throughout the year. Turbid ponds had their maximum populations in March and April followed by a large decline after this time. The early season population increase (Figure 14) was due to the high densities occurring in Pond T-2. Pond T-2 also had the highest average density for the year (Table 3). Clear ponds retained low numbers of individuals throughout the year with no large population maxima in the spring. At no time did the average densities for the clear ponds exceed ten organisms per liter, even when the populations were at their greatest level in May.

Keratella cochlearis was the most numerous and the most frequently encountered of the three sampled rotifers (Figure 14). Both turbid

and clear ponds had large populations in the spring, lasting from March until late June. There was not a significant difference between the population densities in either type of pond. The turbid ponds had three large population peaks while the clear ponds had one large and two lesser ones. Relatively few K. cochlearis remained at the end of the sampling period.

Two copepod genera plus their nauplii stages were common during the study (Figure 15); Cyclops sp., Diaptomus sp. and the nauplii occurred in almost all of the ponds. Neither type of pond had a significantly greater population density of Cyclops sp., but Table 3 does show that the average number of Cyclops sp. in each turbid pond was equal to or greater than that occurring in the clear pond with the greatest density. Turbid pond maxima occurred in April, July, and August, while clear ponds had their largest population in July. Clear ponds never did have the great fluctuations of the turbid ponds, but increased and decreased gradually throughout the year.

Diaptomus sp. occurred in all of the turbid ponds, but existed in only one of the clear ponds (Table 3). The turbid ponds had significantly greater densities and wider fluctuations of Diaptomus sp. than the clear ponds. The turbid ponds attained their greatest population sizes in May, August, September, and October, while the clear pond had their peak in July.

The nauplii did not occur in significantly greater numbers in either of the pond types, and both had their maximum densities in August. The turbid ponds again had considerable more variation throughout the year and reached a population size of over 500 organisms per liter; much greater than the 140 organisms per liter maximum of the clear ponds.

The number of Cladoceran species outnumbered those of either Rotifera or Copepoda. Daphnia sp. was the one group which was found at all times of the year at nearly the same densities in both types of ponds (Figure 16). Neither type of pond had a greater abundance of Daphnia sp. The populations existed at their lowest levels in the early spring and in the fall, with there being a bimodal distribution from late May to early August.

Ceriodaphnia lacustris was found in both clear and turbid ponds, but neither type of pond had a significantly greater amount (Figure 16). During the relatively short time in which they existed, the turbid ponds had the greater average density. Turbid ponds had their greatest abundance of approximately 60-70 organisms per liter in July and August, while the clear ponds had their maximum of 4 organisms per liter in late July.

Bosmina longirostris did not occur in significantly greater numbers in either of the pond types. The time of year had a great affect upon both of the pond types. The turbid ponds had their peak abundance during the early half of the sampling period, while the clear ponds had their greatest population of B. longirostris during the latter half. The clear ponds had a population maximum of approximately 250 organisms per liter, and the turbid ponds had densities which only reached 120 organisms per liter.

Diaphanosoma brachyurum occurred in Ponds T-1 and T-3 and did not occur in any of the clear ponds (Table 3). The populations became evident in early June and disappeared in mid-October, reaching a peak abundance of 15 organisms per liter at one time (Figure 17).

Macrothrix laticornis was found only in Pond T-2 and had its greatest abundance during late July and early August (Table 3; Figure 17). At

one time Pond T-2 had a population density of 64 individuals per liter, but it decreased quickly and was detected no more.

Total zooplankton densities were significantly greater in the turbid ponds than in the clear ponds (Figure 17). Turbid ponds had their peak abundances in the spring, late summer and fall. Clear ponds retained a relatively constant density throughout the year with none of the great fluctuations characteristic of the turbid ponds. The greatest density for total zooplankton in the turbid farm ponds was 1360 organisms per liter, and clear ponds had an average maximum of 460 organisms per liter.

Zooplankton biomass for the clear and turbid ponds is illustrated in Figure 18, and the means for each pond are listed in Table 3. There was a significantly greater biomass per unit volume of water in the turbid ponds. The turbid pond biomass increased in early spring, then steadily declined until the latter part of May. After the decrease the turbid ponds again increased until the end of the sampling period. The clear ponds appeared to fluctuate around a certain point and never had the wide variations and the great standing crops characteristic of the turbid ponds. The biomass of the clear ponds appeared to decline to a low level at the end of the year.

DISCUSSION

Water levels were quite divergent throughout the sampling period (Figure 2). Precipitation and the subsequent runoff appeared to affect the turbid pond water levels more than those of the clear ponds. Spring-fed clear ponds neither increased their water levels during periods of high precipitation nor did they decrease much when rainfall was not available. The underground flow of water into these ponds maintained the water levels near the overflow.

The turbidity patterns, like the water levels, were quite different throughout the year. The fluctuations in water level due to intermittent precipitation and runoff enabled the turbidity to increase in the turbid ponds, especially in the spring of the year (Figure 3). In June, when the rains ceased and the runoff decreased, the turbidity also declined. The clear ponds did not show the great increase in turbidity in the spring, because there were neither great amounts of runoff coming into the ponds nor any sizeable fluctuations in the water level. The clear ponds were located in less heavily grazed, well-sodded drainage areas which allowed little soil erosion and promoted better water retention, while turbid ponds were located in more heavily grazed, easily eroded areas which permitted surface runoff. These results coincided with Smrchek's (1970) which showed that the silt-clay bottoms and the drainage patterns affected the clarity of the ponds.

The turbidity during April, May, and June may have been too great to allow the growth of phytoplanktonic plants in the turbid ponds, because the densities of chlorophyll-a were sharply reduced. Macrophytes, which ordinarily grow well in clear ponds, also may have been inhibited from thriving during this time of early development. These plants were actually prevented from growing in all of the turbid ponds throughout the sampling period. The turbidity existing in the turbid ponds after late June was not enough to restrict the occurrence of phytoplankton to near the surface as described by Irwin and Claffey (1968). Turbid ponds in the present study had an average Secchi disc reading of approximately 28 centimeters; four to five times that of the ponds studied by Irwin and Claffey (1968). Prophet (1966) determined the

depth of the euphotic zone by estimating the depth to which 1% of the surface illumination penetrated. Secchi disc readings were compared with the results of the photometer, and the depth to which 1% of the surface illumination penetrated was equal to four times the Secchi disc depth. Based on the 28 centimeter average Secchi disc reading, the euphotic zone in the turbid ponds would be nearly equal to one-half the average depth of the ponds. The average Secchi disc reading for the clear ponds was 82 centimeters, and the euphotic zone would reach to near the bottom in all of the ponds, allowing plant growth at all depths.

The turbidity caused by runoff contains many kinds of materials; some of which are organic in nature. These organic compounds require oxygen for decomposition and liberate carbon dioxide. This may be why the turbid ponds having a higher organic content, had large amounts of carbon dioxide in the spring of the year. The lowered turbidity from late June on to the end of the year promoted increased chlorophyll-a production and increased utilization of the nutrient salts and carbon dioxide.

The temperature of the water is essentially dependent upon the solar energy absorbed, and the rate of the chemical reactions is governed to a large extent by the thermal energy. Therefore, it is vital to the biological system that there is a yearly temperature cycle. The water temperatures increased in the spring, arrived at their maximum and decreased in the summer, and sharply declined during the fall (Figure 4). Thermal stratification developed in late April and early May, and destratification occurred in late August and early September. Homothermal pond temperatures occurred in mid-March and again in mid-October. This information agrees with that of Smrchek (1970),

Tiemeier (1966), Wallen (1955), and Willis (1959). The ponds in the present study did not demonstrate the turbidity-temperature relations described by Butler (1962) and Wallen (1951). The bottom temperatures were not lower in turbid ponds than in clear ponds, and thermal stratification was not more pronounced.

No information has been presented concerning the particulate organic matter in Kansas farm ponds. These particulates consist of small phytoplanktonic, detrital, and other organic matter which are small enough to be used as food for filter-feeding zooplankton. An increase in the phytoplankton caused a resulting increase in the particulate organics. Particulate organic concentrations were usually higher nearer the surface in turbid ponds and higher nearer the bottom in clear ponds (Figure 5). This may have been due to the location of the photosynthetic zone, since the chlorophyll-a concentrations fluctuated with the particulate organic matter ($R^2 = 0.86$). The highest average particulate organic density was greater in the turbid ponds ($4,950 \text{ mgC/m}^3$) than in the clear ponds (2700 mgC/m^3), and the average particulate organics for the turbid ponds was greater than that for the clear ponds over the whole sampling period. This may contribute to the fact that the total zooplankton were occurring in significantly greater densities in the turbid ponds. Novak (1969) found a wide range of particulate organic matter concentrations in Tuttle Creek Reservoir, going from 182 mgC/m^3 in May to $6,720 \text{ mgC/m}^3$ in July. Turbid ponds displayed the wide ranges similar to that of Tuttle Creek, while the clear ponds were more gradual in their fluctuations.

The alkalinity of a water is the measure of its capacity to neutralize acids, primarily due to the salts of weak acids. Bicarbonates

represent the major form of alkalinity, since they are formed in considerable amounts from the action of carbon dioxide upon basic materials in the soil. The carbonic acid generally encounters calcareous rock, especially in the deeper strata of mineral soil. Although quite insoluble, the limestone easily goes into solution as calcium bicarbonate in the presence of carbonic acid. The bicarbonate content of the water is dependent on two factors: the calcium content of the earth and the carbon dioxide content of the water. For calcium bicarbonate to be stable a certain surplus (free) amount of carbon dioxide must remain in solution.

The turbid ponds apparently had sufficient amounts of carbon dioxide, but lacked the quantities of calcium needed to combine with carbonic acid. This apparent shortage of calcium helped to prevent the total alkalinity from increasing to a high level. Clear ponds occurred in areas high in limestone, which formed larger amounts of calcium bicarbonate. Since all of the clear ponds received water by springflow, this would also give the water additional time to pass by high limestone understrata. The free carbon dioxide appeared to be adequate to maintain the calcium bicarbonate in solution.

Specific conductance measurements are often used to obtain a rapid estimate of the dissolved solids (electrolyte) content of a water sample. In most natural waters the predominant anions are bicarbonates associated mainly with calcium and to a lesser degree with magnesium. One can readily understand why the clear ponds had a higher average specific conductivity (Figure 7), especially when the ionized calcium bicarbonate molecules are in greater supply. Turbid ponds, with lower levels of total alkalinity, responded in a proportionate

manner by having less specific conductivity. When comparing Figures 6 and 7, one can see the similarities in the plots.

The hydrogen-ion concentration of water is a very important characteristic of an aquatic community, because many organisms thrive best in areas where there is a stable, optimum pH. Buffers play an extremely important role in the life of organisms because they serve to prevent fluctuations in pH. There was a difference in the surface water pH values for the two types of ponds, probably due to the more organic nature of the turbid ponds. The resultant release of carbon dioxide served to depress the pH more in the turbid ponds. Bottom water in both types of ponds were blocked off from the surface by thermal stratification and developed high carbon dioxide levels, low oxygen concentrations, and lower pH values (Figure 8, 9, 10). There was no difference between the bottom water pH values in either of the two types of ponds.

Carbon dioxide is a normal component of all natural waters. It serves as one of the vital components of alkalinity by combining with lime and water to form calcium bicarbonate. The free carbon dioxide concentrations in the farm ponds were inversely related to the hydrogen-ion densities ($R^2 = 0.81$). Similarly, Smrchek (1970), Tiemeier and Elder (1957), and Wiebe (1930) found pH to be inversely correlated with free carbon dioxide. The pH of the surface water gradually increased throughout the study period because the carbon dioxide was slowly being lost to photosynthesis, to the atmosphere, and to the maintenance of the alkalinity complex. There was also an inverse relationship between the dissolved oxygen concentrations and the carbon dioxide levels in the farm ponds ($R^2 = 0.50$). Carbon dioxide concentrations were being increased while oxygen levels decreased, especially in the bottom water

of the ponds. Since carbon dioxide is also the end product of anaerobic bacterial oxidation, its concentration is not entirely limited by the amount of dissolved oxygen originally present. Thus it is not uncommon to encounter waters with high carbon dioxide levels.

Discussions about dissolved oxygen in farm ponds have been presented by Schultz (1952), Smrcek (1970), Surber and Olson (1936), Wallen (1955), and Willis (1959). Oxygen and carbon dioxide are the two major components in metabolism, and whenever a chemical gradient of these two occurs, their distributions are usually opposite. Therefore, it was expected that the stratification of oxygen in the farm ponds would be opposite to that of carbon dioxide (Figure 9, 10). In the productive surface layers the carbon dioxide was decreased by photosynthesis, and the oxygen increased. In the lower, tropholytic regions oxidation processes decreased the oxygen and increased the carbon dioxide.

Temperature is an important characteristic that influences the oxygen utilization. The solubility of oxygen also varies indirectly with temperature. This latter inverse relationship was found in the present study ($R^2 = 0.71$). Depletion of the oxygen supply to a low concentration will endanger all of the organisms dependent upon it, and will restrict them to areas where oxygen occurs. Anaerobic conditions, particularly common in the hypolimnion during the summer, can prevent oxygen requiring individuals from utilizing the bottom water of the farm pond during the time of greatest aquatic productivity. The surface water concentrations in the present study did not decline to the point of that occurring in the bottom water, but closely followed the saturation value for the water temperature. Bottom water concentrations fell far below that for saturation, but anaerobic conditions for all

ponds were generally avoided during the summer, except for late July and early August. Ponds T-1, T-2, and C-3 were the only ponds to become anaerobic, even though the averages show no anoxic conditions (Figure 10).

Nitrate-nitrogen and orthophosphate are of particular interest, since they are the forms which plants can utilize and animals can not. Animals are dependent ultimately upon plants to provide this protein source. Nitrogen and phosphorus are both essential to the growth of algae, and limitation in amounts of these elements is usually the factor that controls their rate of growth. Nitrate-nitrogen concentrations for surface and bottom water were much higher in the spring, dropped to a lower level in June, and became stable at a somewhat higher level the rest of the year (Figure 11). This trend was also described by Smrchek (1970) and Surber and Olson (1936). The turbid pond nitrate-nitrogen concentrations were much higher in the spring than those of the clear ponds. A larger amount of these nitrates had to be utilized in order to reduce them down to the levels occurring in the clear ponds during the summer. The higher concentrations of nitrate-nitrogen in the late winter and early spring may have been due to the decomposition and release of nitrogen compounds and to the distributing effect of the spring overturn. Decreasing concentrations of nitrates were due mainly to the increased utilization and consequent reduction by aquatic processes.

Orthophosphate followed the same general trend of the nitrate-nitrogen (Figure 12). The clear ponds did not show the consistently high levels in the spring, but displayed a short term increase and then a decrease. Apparently the release of orthophosphates in the clear ponds during the cooler times of the year was not as

great as that of the turbid ponds. The orthophosphate in the clear ponds may have been utilized more quickly at its time of greatest availability; probably due to its lower maximum levels. Zeller (1953), Bennett (1971), and Swingle (1947) have discussed the fact that orthophosphate may be more limiting than nitrate-nitrogen, and when it is in higher concentrations, it may be reduced very quickly by plants. Rottner (1963) also noted that it could be stored when levels were high.

Chlorophyll-a information pertaining to Kansas farm ponds had not been investigated previously. Turbidity in the turbid ponds had an effect upon the chlorophyll-a concentrations, especially during times of maximum runoff. The levels decreased rapidly during this time of reduced clarity. Increased clarity may have been a controlling factor which started the great recovery of chlorophyll-a (phytoplankton) during the latter part of June (Figure 13). Chlorophyll concentrations were higher on the bottom in clear ponds, but higher on the surface in turbid ponds (Figure 13; Table 2). This may have been due to the location of the photosynthetic zone and the effect of turbidity on it. The turbid ponds became more shallow as the water level dropped throughout the sampling period. This shallowness plus the cooler weather in August, which caused a short-term breakdown of thermal stratification at night, may have caused some nutrient cycling by water overturn which resulted in a phytoplanktonic population increase. Chlorophyll-a concentrations in the euphotic zone were inversely related to the amounts of orthophosphate and nitrate-nitrogen and Prophet (1966) reported similar results in his analysis. The farm ponds in this study appeared to have more chlorophyll per unit volume than reservoirs (Taylor, 1971; Prophet, 1966) or lakes (Prophet,

1964) in other parts of Kansas. The turbid ponds apparently had enough orthophosphate and nitrate to allow the development of algal blooms that approached eutrophic conditions as suggested by Sawyer, (1952). The turbid ponds had no macrophytes occurring in the pond basin thus nearly all of the nutrients went into the production of phytoplanktonic algae and were not tied up in larger longer-living plants.

All of the cladocerans and copepods occurring in the farm ponds studied are contained in species lists and observations by Armitage (1961), Ahlstrom (1934), Leonard and Ponder (1949), Prophet, Andrews and Goulden (1959), Prophet and Waite (1974), and Smrchek (1970). Smrchek (1970), Ahlstrom (1934), and Surber and Olson (1936) noted the presence of rotifers such as Asplanchna sp., Keratella cochlearis, and Filinia longiseta. Pennak (1957) described these genera as being cosmopolitan in nature. Asplanchna can be partly predaceous, but most of the characteristic genera (such as Keratella and Filinia) feed upon small particulate materials, both living and dead, by concentrating them at the mouth. The somewhat greater populations of rotifers in the turbid farm ponds may have been due to the overall greater average concentrations of particulate organic matter. Whenever two species of the same genera were present, one was always much more abundant than the other. K. cochlearis and K. quadrata sometimes occurred simultaneously, but the former was nearly always much more abundant.

Pennak (1957) states that cyclopoid copepods have the mouth parts modified for seizing unicellular plants and animals, as well as bits of debris. Freshwater calanoids are less selective filtration feeders which subsist on all types of living and dead particulate matter. On this basis Diaptomus sp. could exist in an area where there are suitable particulates, such as those occurring in the turbid ponds.

Many times though, the cyclopoid is an active predator feeding chiefly on the calanoid copepod, Diaptomus. When no species of Diaptomus are present, cladocerans and rotifers can potentially form the main food source (Fryer, 1957). One can notice that the potential prey species, Diaptomus, had times of abundance which did not coincide with those of the predator species. This could have been caused by the reduction or constant control of the prey species by the predator.

The number of cladoceran species outnumbered the ones that were present in each of the other two groups. The cladocerans are primarily filter feeders and occurred in the largest densities in the ponds where food items were at an optimum. Most of the time the five genera were in a greater abundance in the turbid ponds where a larger average density of particulates and phytoplankton occurred. Species such as Daphnia sp. and Bosmina longirostris occurred in about equal average numbers and peak abundances, no matter which pond type each species was collected from. Daphnia sp. appeared to have the same population curves in both clear and turbid ponds. Bosmina longirostris had its greatest abundance in the clear ponds during the late summer and early fall when particulate organics and phytoplankton were plentiful, but had its greatest densities in the turbid ponds during the spring, with another smaller increase in Augst. For the short period of time they existed, Ceriodaphnia lacustris did have a greater average population in the turbid ponds (Figure 16). Diaphanosoma brachyurum occurred only in Ponds T-1 and T-3, while Macrothrix laticornis existed entirely in Pond T-2. Both species were large in size and apparently found their optimum conditions in the turbid ponds.

Total zooplankton numbers and zooplankton biomass were greater in the turbid ponds, and this may have been due to the more substantial

food supply in the turbid ponds. Even though, statistically, the values for the food parameters between the two types of ponds were not different, there was a larger average available food supply in the turbid ponds. The photosynthetic zone was not restricted to the first few inches near the surface in the turbid ponds, but extended down to a depth which allowed the phytoplankton to become a potential, adequate food supply for the plankters. The nutrients in the turbid ponds went into the production of phytoplankton rather than into macrophytes which bind the nitrates and phosphates and prevent the quicker rate of recycling characteristic of the unicellular algae. During the first one-half of the sampling period many of the phytoplankton species were green algae, which make up a more favorable diet for the zooplankton than when blue-green algae are consumed. Decomposing planktonic organisms plus organics brought in by runoff both provide particulate organics to the aquatic system. The particulate organic matter analysis showed that there was no statistical difference between the turbid and the clear ponds, but when noting the data from Figure 5, one can see an average which was greater in the turbid ponds. When ample food supply is available, more and larger zooplankton can be supported. This is reflected in the fact that the turbid ponds, especially T-2, had more zooplankton (Table 3), and that these ponds supported a heavier weight of plankters per unit volume of water.

Table 1. Morphometric data for the six experimental ponds.*

Pond Number	<u>Clear Ponds</u>			<u>Turbid Ponds</u>		
	C-1	C-2	C-3	T-1	T-2	T-3
Area When Full (hectares)	0.16	0.26	0.69	0.57	0.43	0.65
Average Area During Study (hectares)	0.15	0.26	0.69	0.49	0.37	0.57
Volume When Full (m^3)	1586	2701	9626	8495	4049	7136
Average Volume During Study (m^3)	1472	2633	9626	7362	3030	6116
Maximum Depth When Full (m)	2.26	2.47	3.08	3.66	2.19	2.87
Average Maximum Depth During Study (m)	2.19	2.44	3.08	3.38	1.83	2.65
Shoreline Development	1.7.	1.67	1.86	1.79	1.43	1.15

*Each observation represents the average for the fifteen sampling periods.

Table 2. Average values for the physical, chemical, and biological variables measured in the three clear (C) and the three turbid (T) farm ponds during the period March through October, 1974. Bottom water values are in parentheses.*

Measured Variables	C-1	C-2	C-3	T-1	T-2	T-3
Secchi disc (cm)	61	104	81	38	23	25
Water Level (cm)	- 6.9	- 2.5	+ 2.8	-26.8	-33.5	-23.4
Turbidity (JTU)	32 (30)	14 (17)	32 (108)	81 (61)	142 (142)	172 (198)
Temperature (°C)	20.9 (17.1)	20.4 (17.7)	21.8 (15.5)	21.6 (15.2)	21.2 (17.4)	20.7 (16.9)
Particulate organic matter (mgC/m ³)	1420 (1450)	756 (1027)	1036 (1848)	1020 (890)	5370 (5270)	1930 (1870)
Specific Conductivity (micromhos/cm)	384 (407)	422 (434)	224 (214)	251 (257)	292 (303)	221 (226)
Hydrogen-ion concentration	8.2 (7.9)	8.3 (8.1)	7.9 (7.4)	8.0 (7.6)	7.7 (7.3)	7.9 (7.7)
Total Alkalinity (ppm as CaCO ₃)	176 (188)	195 (201)	96 (92)	113 (118)	101 (105)	97 (100)
Dissolved oxygen (ppm)	8.4 (5.0)	8.4 (5.9)	8.6 (3.7)	7.9 (3.7)	8.1 (3.6)	8.3 (5.6)
Free carbon dioxide (ppm)	1.9 (5.6)	1.3 (3.7)	3.0 (8.6)	2.9 (7.1)	8.7 (12.6)	2.1 (4.1)
Nitrate-nitrogen (ppm)	0.38 (0.44)	0.42 (0.48)	0.62 (0.66)	0.46 (0.76)	0.71 (0.82)	0.46 (0.62)
Orthophosphate (ppm)	0.22 (0.04)	0.05 (0.16)	0.14 (0.19)	0.21 (0.52)	1.12 (1.67)	0.25 (0.14)
Chlorophyll-a (mg/m ³)	22.3 (32.6)	18.5 (24.0)	31.2 (46.2)	16.8 (12.7)	173.4 (145.0)	26.8 (25.6)

*Each observation represents the average for the fifteen sampling periods.

Table 3. Average values for zooplankton species (no./l), total zooplankton (no./l), and zooplankton biomass (mg/l) occurring in the three clear (C) and the three turbid (T) farm ponds during the period March through October, 1974.*

<u>Zooplankton Species</u>	<u>Ponds</u>					
	<u>C-1</u>	<u>C-2</u>	<u>C-3</u>	<u>T-1</u>	<u>T-2</u>	<u>T-3</u>
<u>Filinia longiseta</u>	0.3	0.0	7.4	68.2	63.2	27.8
<u>Asplanchna</u> sp.	3.2	0.3	0.0	4.1	59.3	3.0
<u>Keratella cochlearis</u>	113.0	18.3	29.4	150.2	79.2	25.4
<u>Cyclops</u> sp.	24.7	18.8	5.7	30.4	132.2	24.7
<u>Diaptomus</u> sp.	0.0	0.0	10.2	18.4	80.2	23.7
copepod nauplii	59.0	125.8	42.0	53.0	359.8	144.9
<u>Daphnia</u> sp.	0.1	36.6	27.8	3.9	22.1	12.3
<u>Ceriodaphnia lacustris</u>	0.0	0.9	0.6	5.9	0.1	52.0
<u>Bosmina longirostris</u>	172.5	33.9	12.3	54.9	0.9	18.6
<u>Diaphanosoma brachyurum</u>	0.0	0.0	0.0	2.5	0.0	6.8
<u>Macrothrix laticornis</u>	0.0	0.0	0.0	0.0	6.1	0.0
Total Zooplankton	372.8	238.2	135.4	580.0	803.1	339.2
Zooplankton Biomass (mg/l)	0.1	0.2	0.2	0.2	1.2	0.4

*Each observation represents the average for the 15 sampling periods.

Figure 2. Average water levels (deviations from overflow) for the clear and turbid farm ponds located in Riley and Pottawatomie Counties, Kansas.

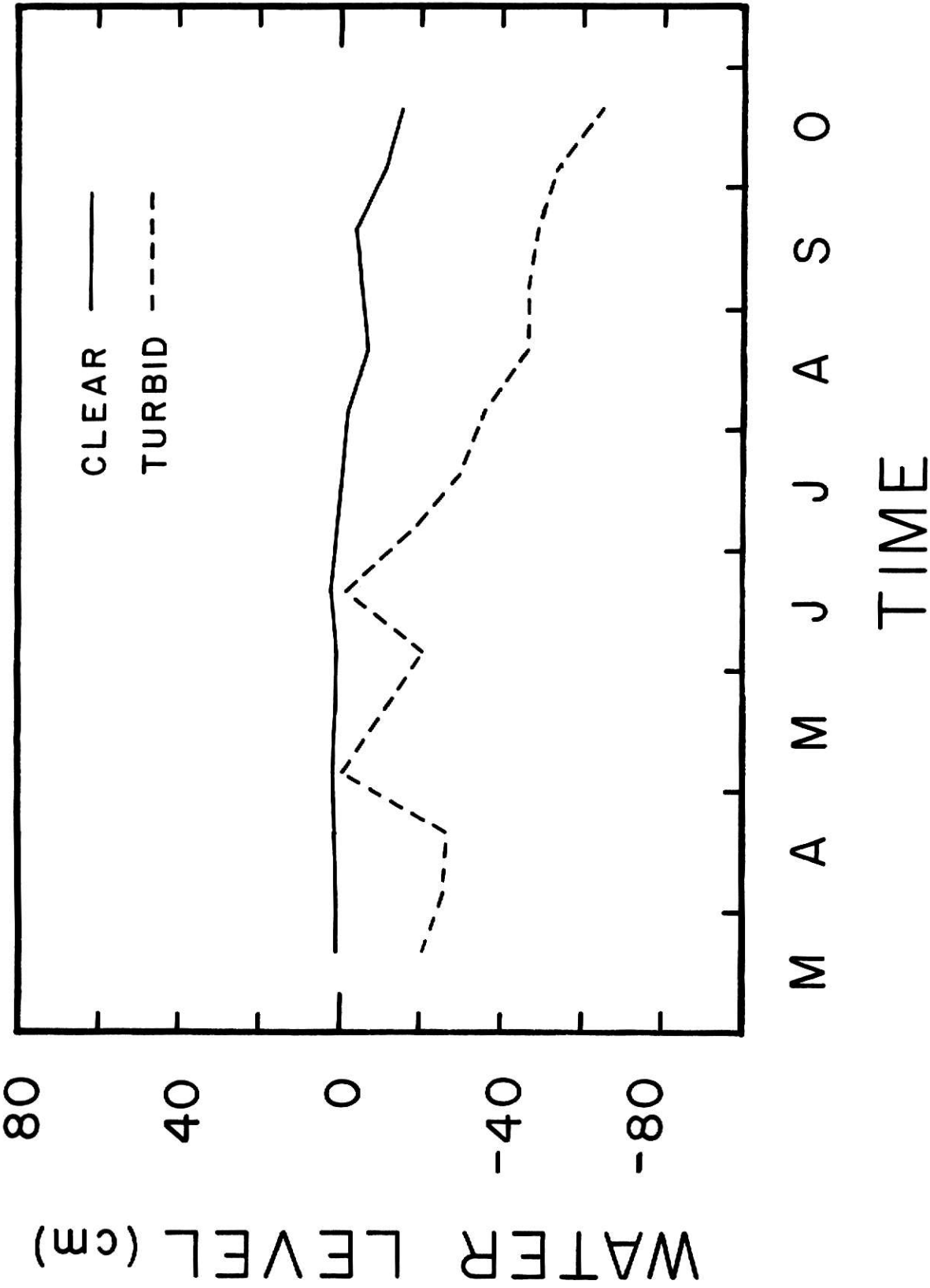


Figure 2

Figure 3. Average turbidity (JTU's) for the clear and turbid farm ponds located in Riley and Pottawatomie Counties, Kansas.

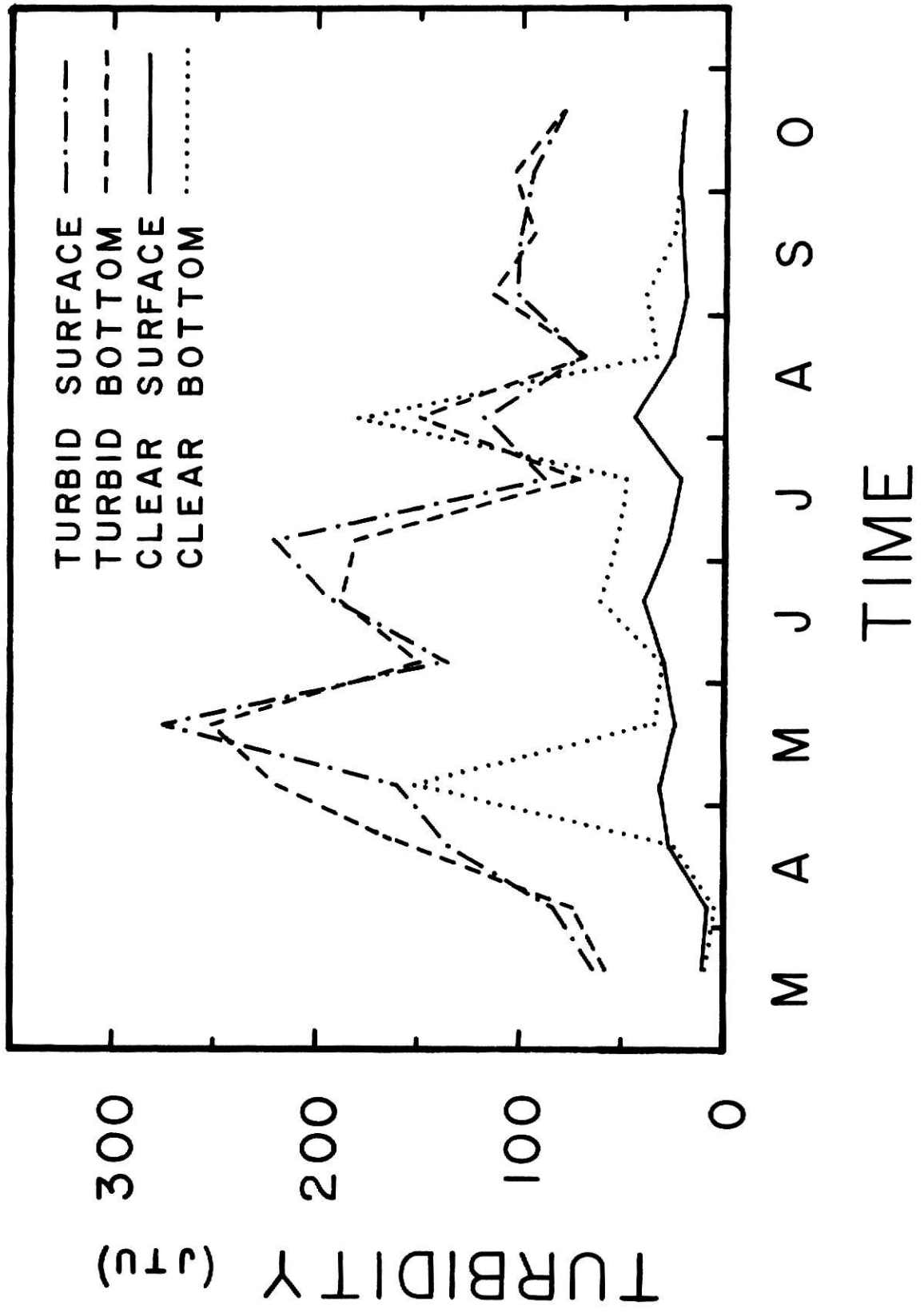


Figure 3

Figure 4. Average temperature (degrees Centigrade) for the clear and turbid farm ponds located in Riley and Pottawatomie Counties, Kansas.

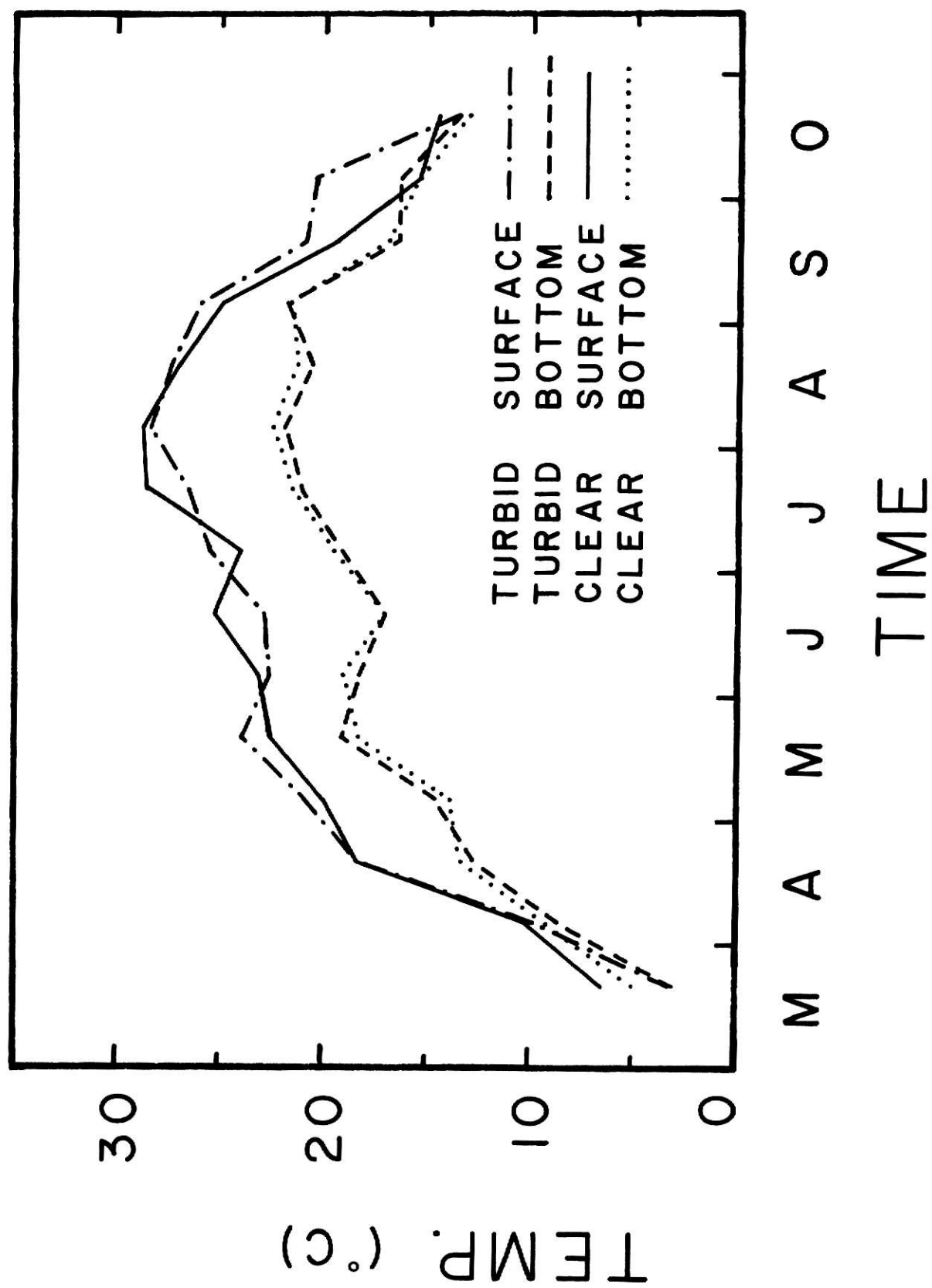


Figure 4

Figure 5. Average particulate organic matter (mg. Carbon/m³) for the clear and turbid farm ponds located in Riley and Pottawatomie Counties, Kansas.

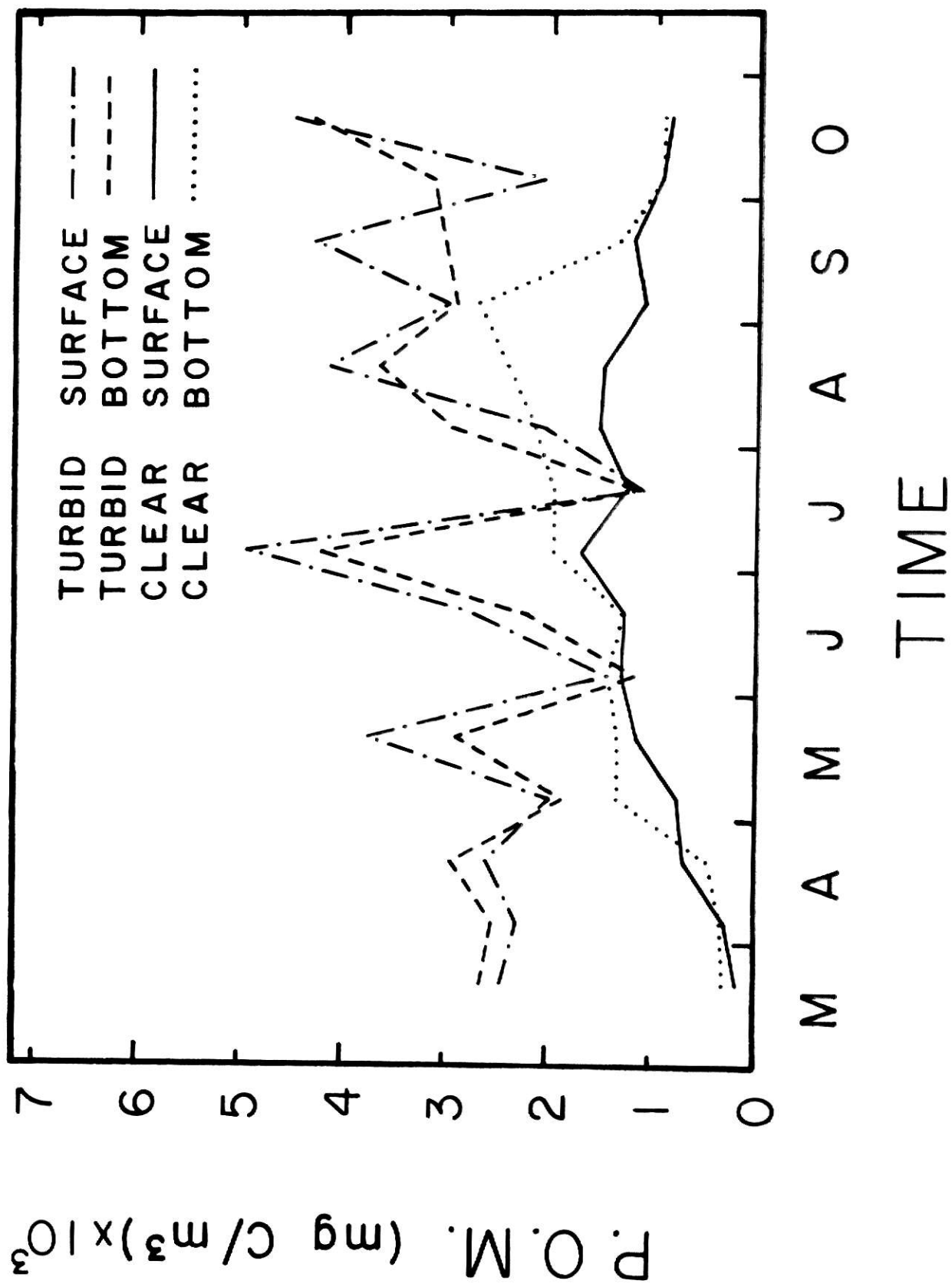


Figure 5

Figure 6. Total alkalinity (ppm as CaCO_3) for the clear and turbid farm ponds located in Riley and Pottawatomie Counties, Kansas.

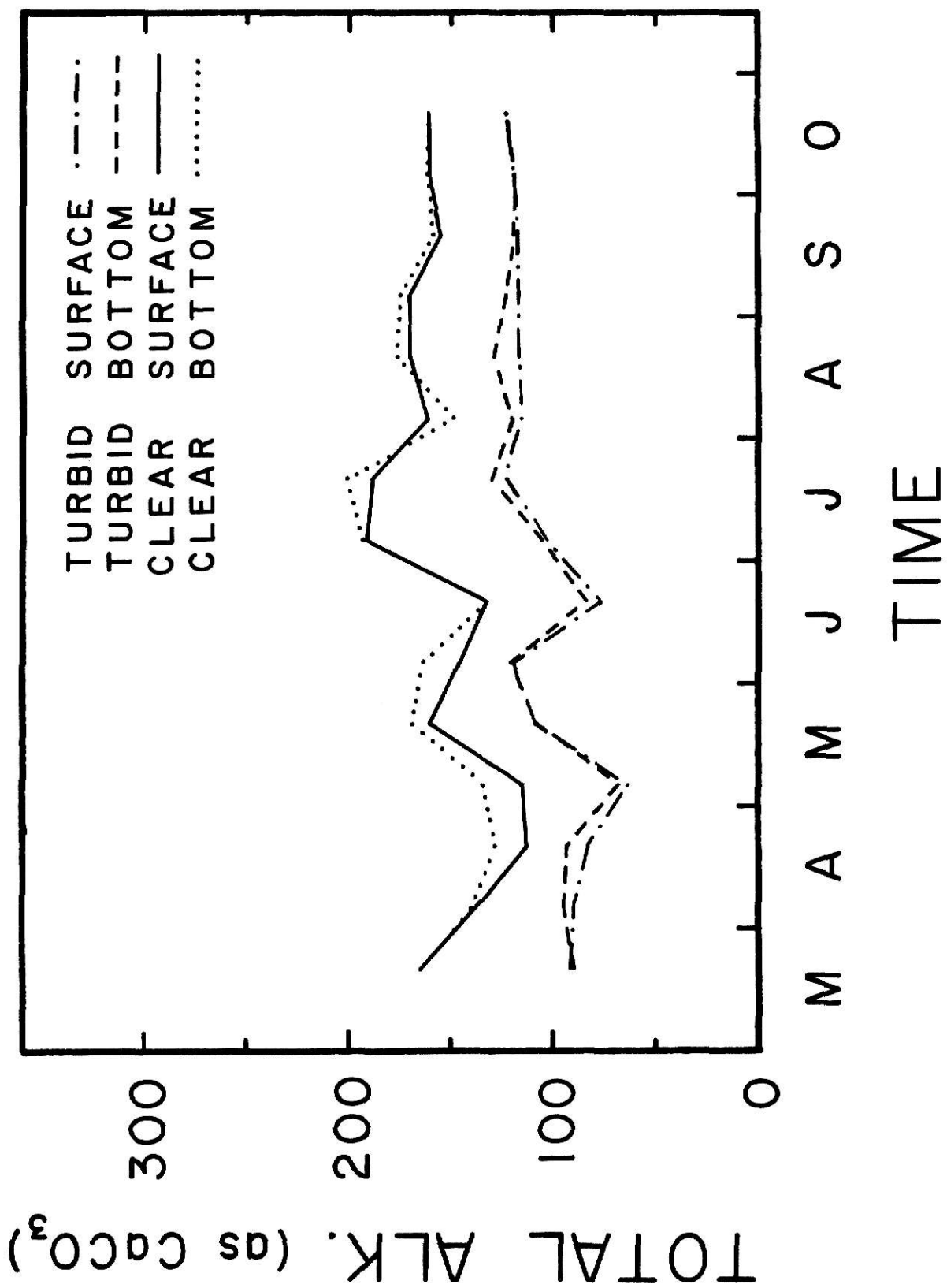


Figure 6

Figure 7. Average specific conductivity (micromhos/cm.) for the clear and turbid farm ponds located in Riley and Pottawatomie Counties, Kansas.

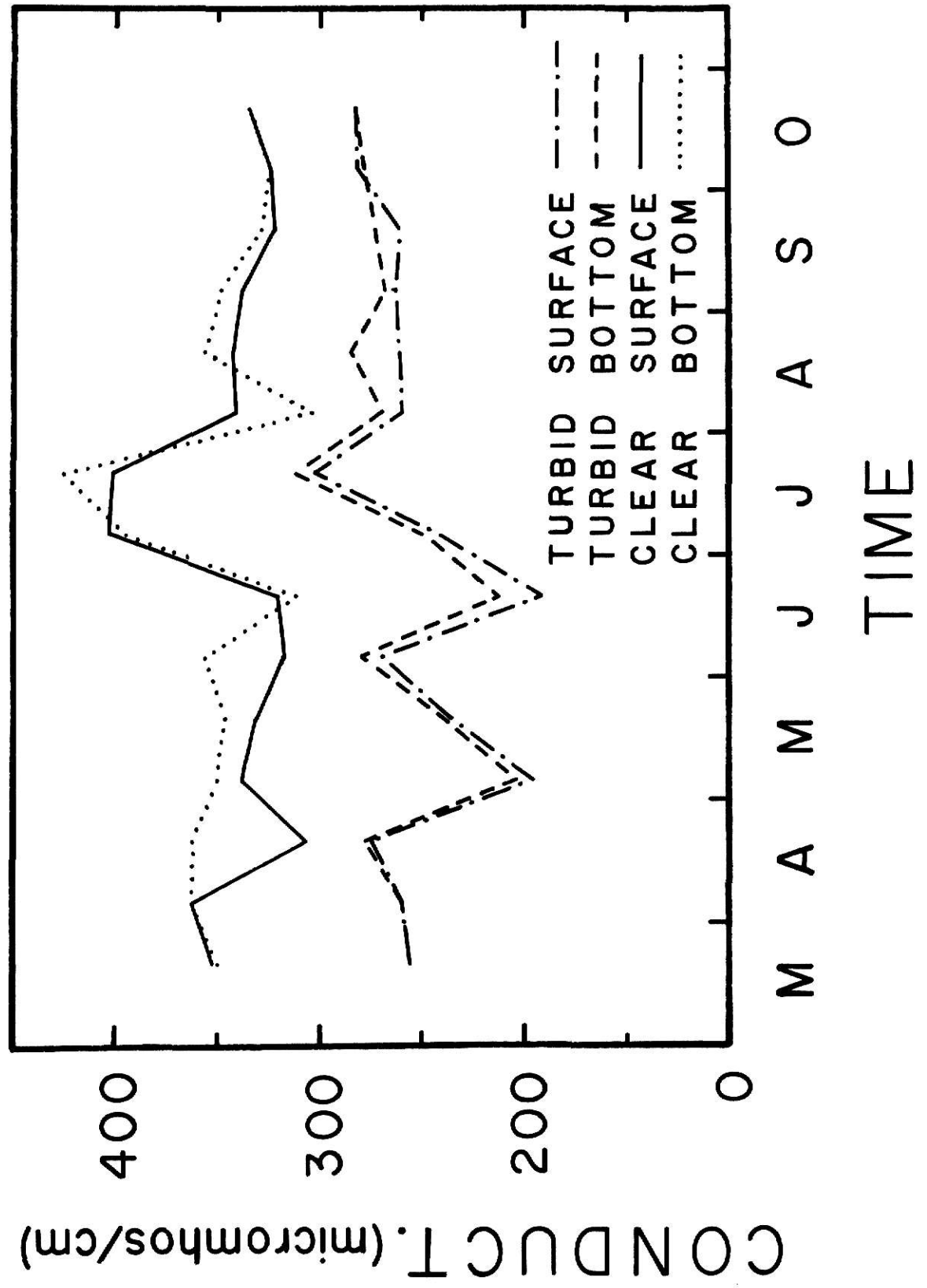


Figure 7

Figure 8. Average hydrogen-ion concentration for the clear and turbid farm ponds located in Riley and Pottawatomie Counties, Kansas.

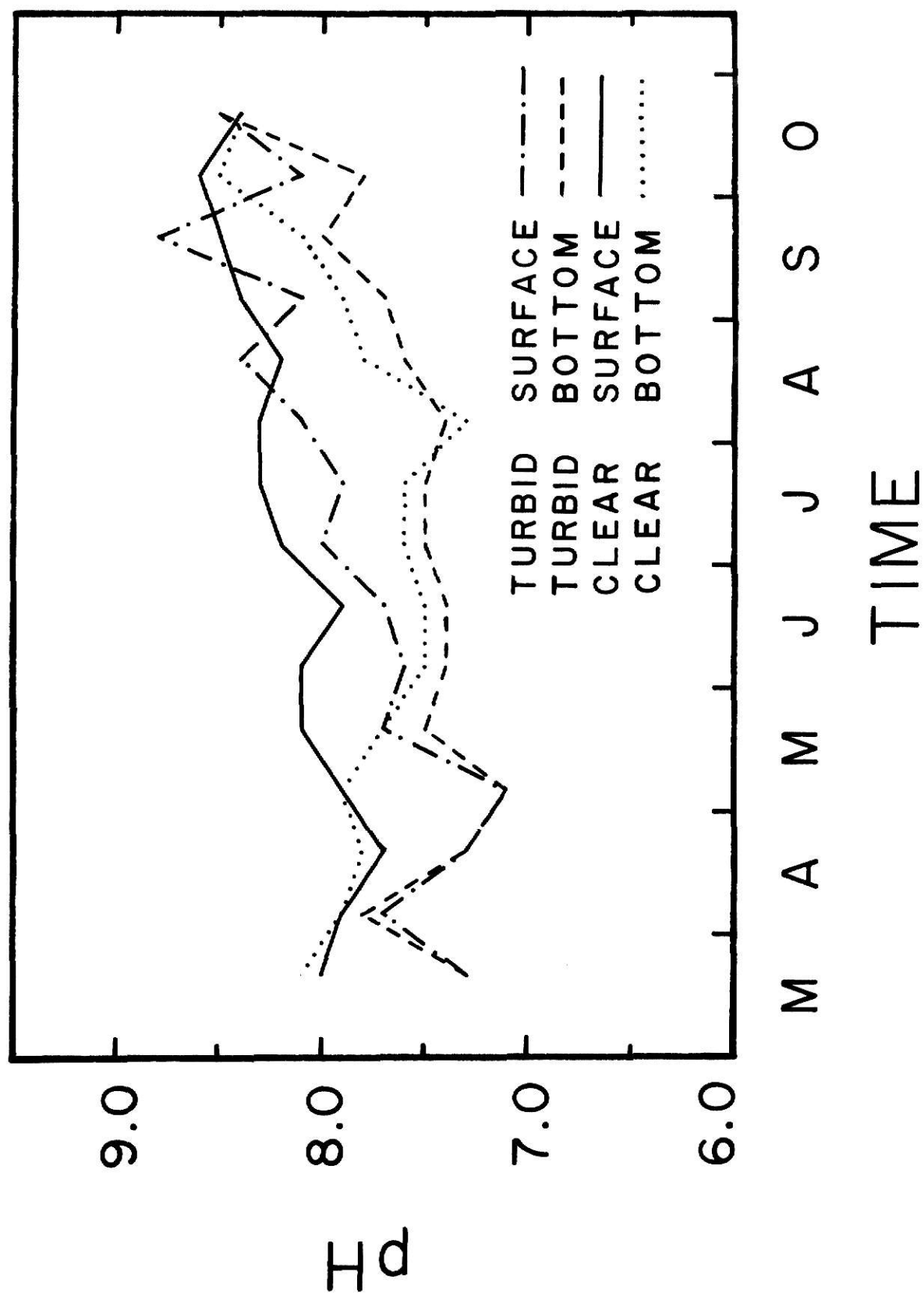


Figure 8

14

15

Figure 9. Average free carbon dioxide concentrations (ppm) for the clear and turbid farm ponds located in Riley and Pottawatomie Counties, Kansas.

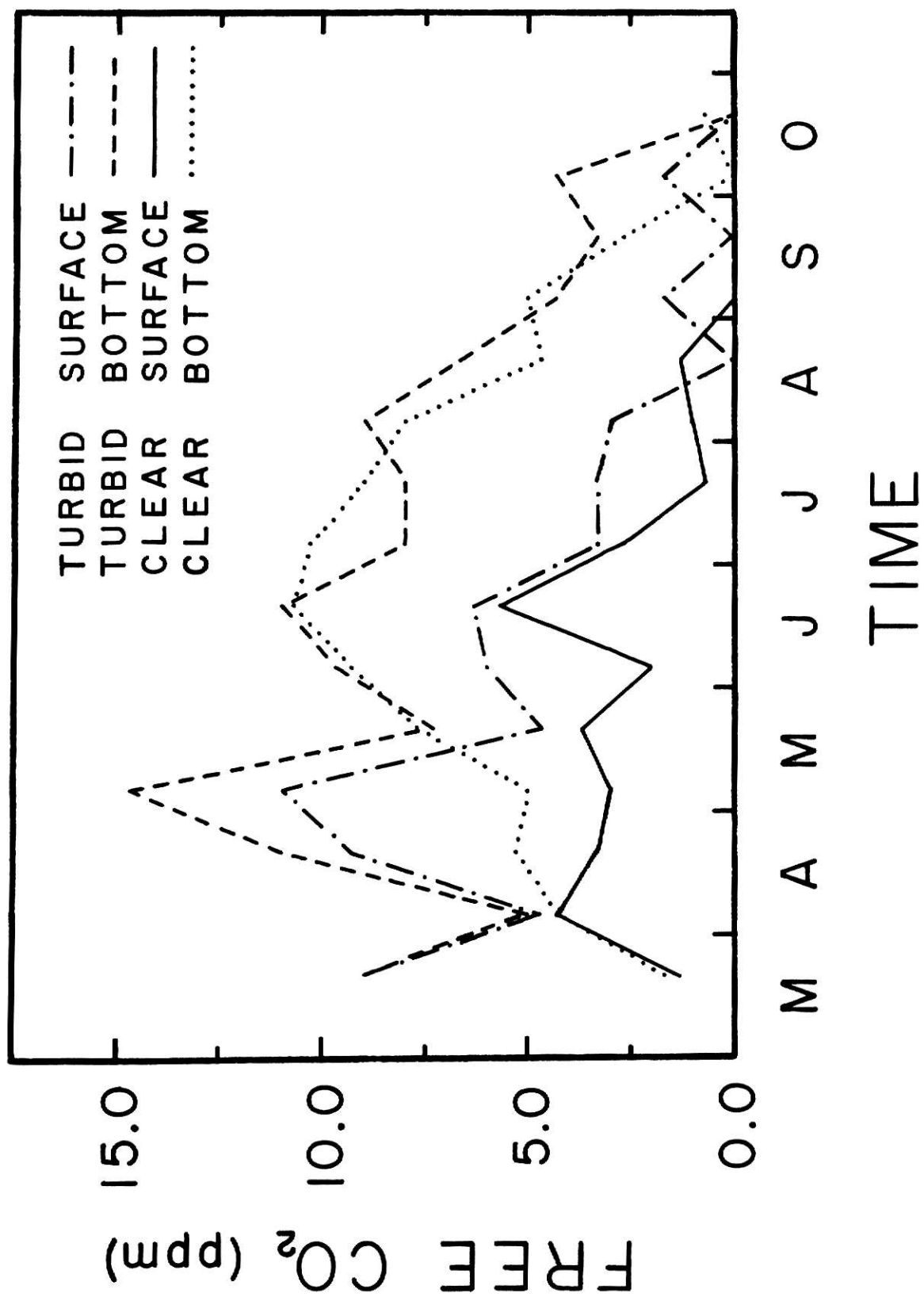


Figure 9

Figure 10. Average dissolved oxygen concentrations (ppm) for the clear and turbid farm ponds located in Riley and Pottawatomie Counties, Kansas.

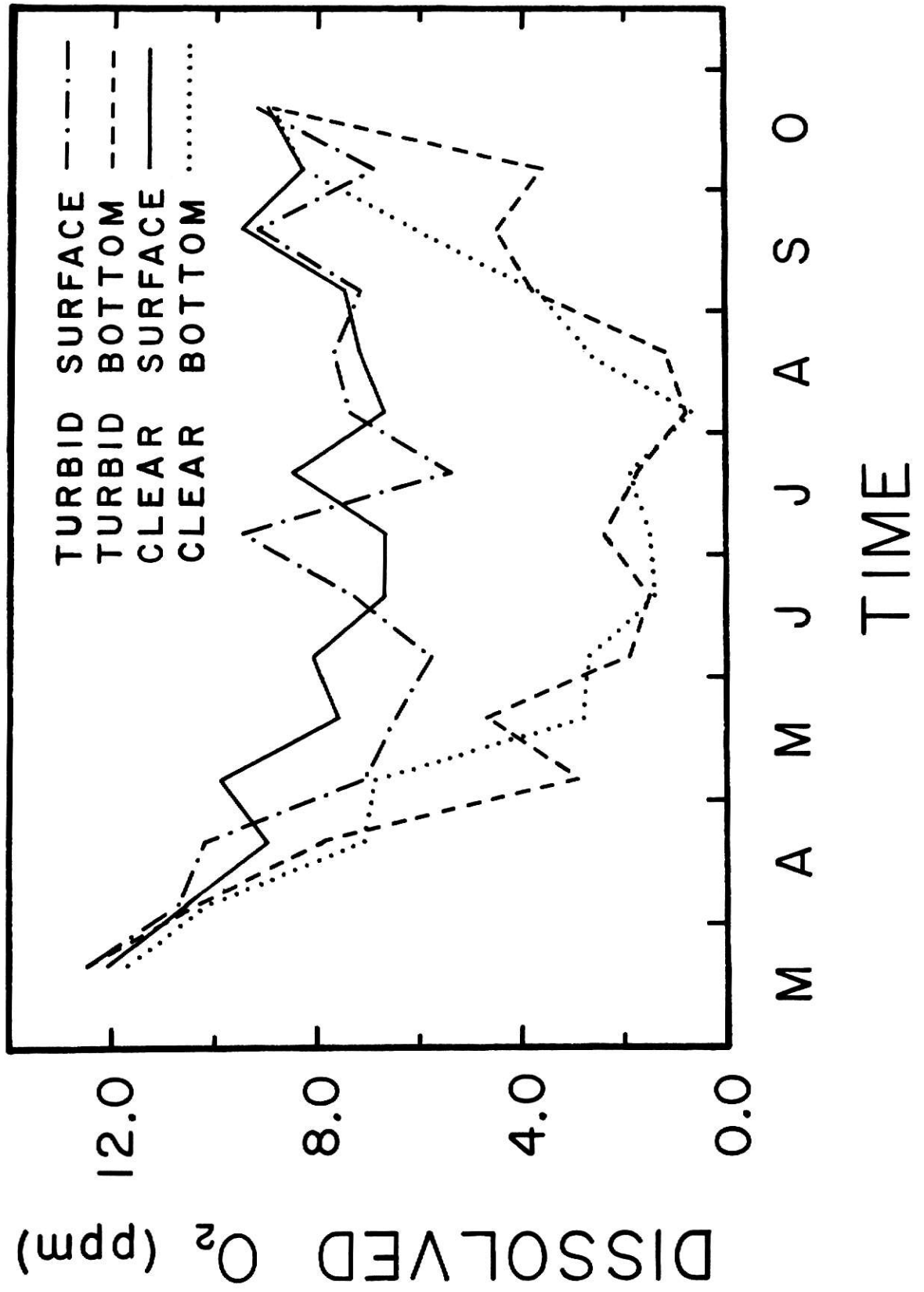


Figure 10

Figure 11. Average nitrate-nitrogen concentrations (ppm) for the clear and turbid farm ponds located in Riley and Pottawatomie Counties, Kansas.

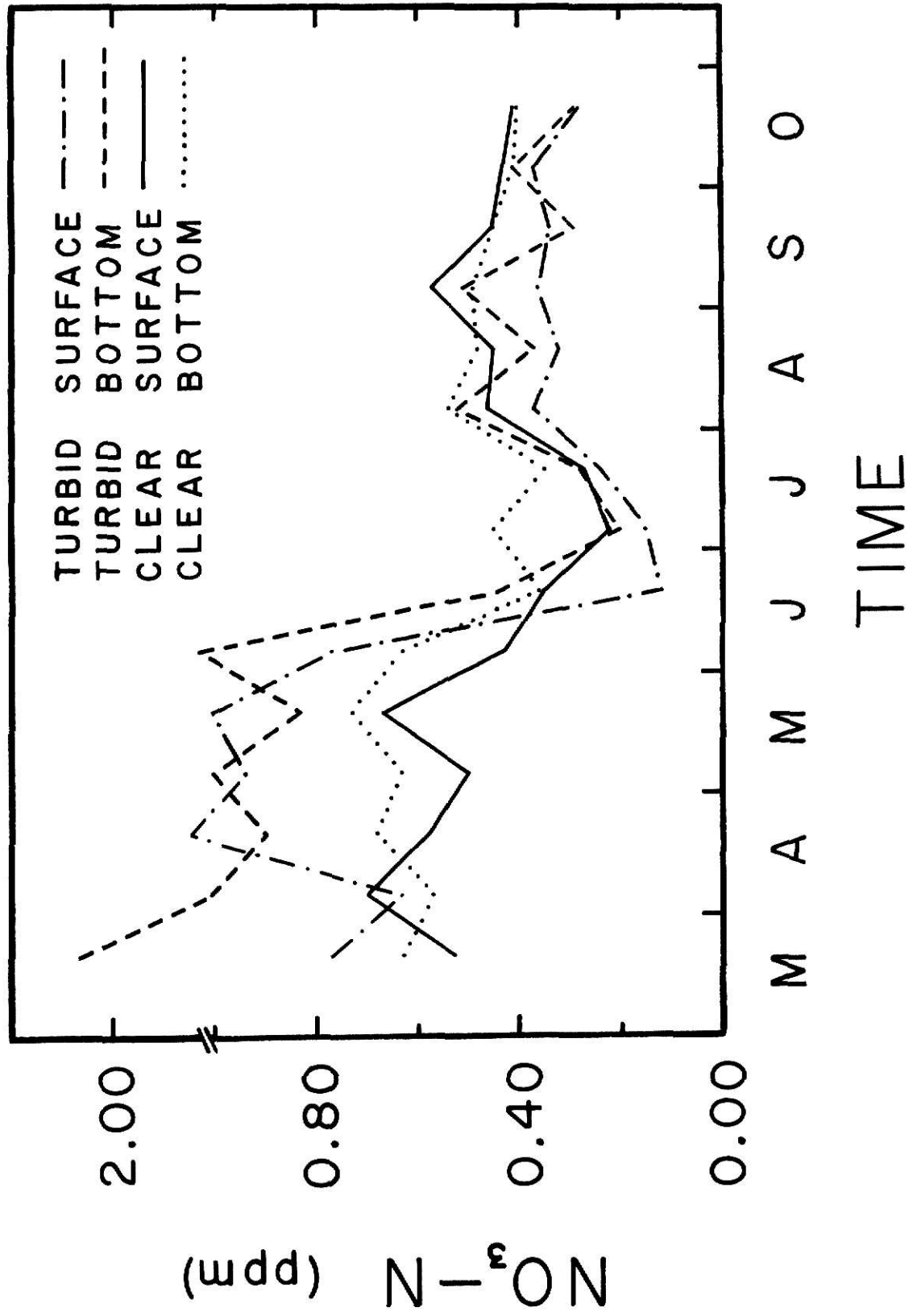


Figure 11

Figure 12. Average orthophosphate concentrations (ppm) for the clear and turbid farm ponds located in Riley and Pottawatomie Counties, Kansas.

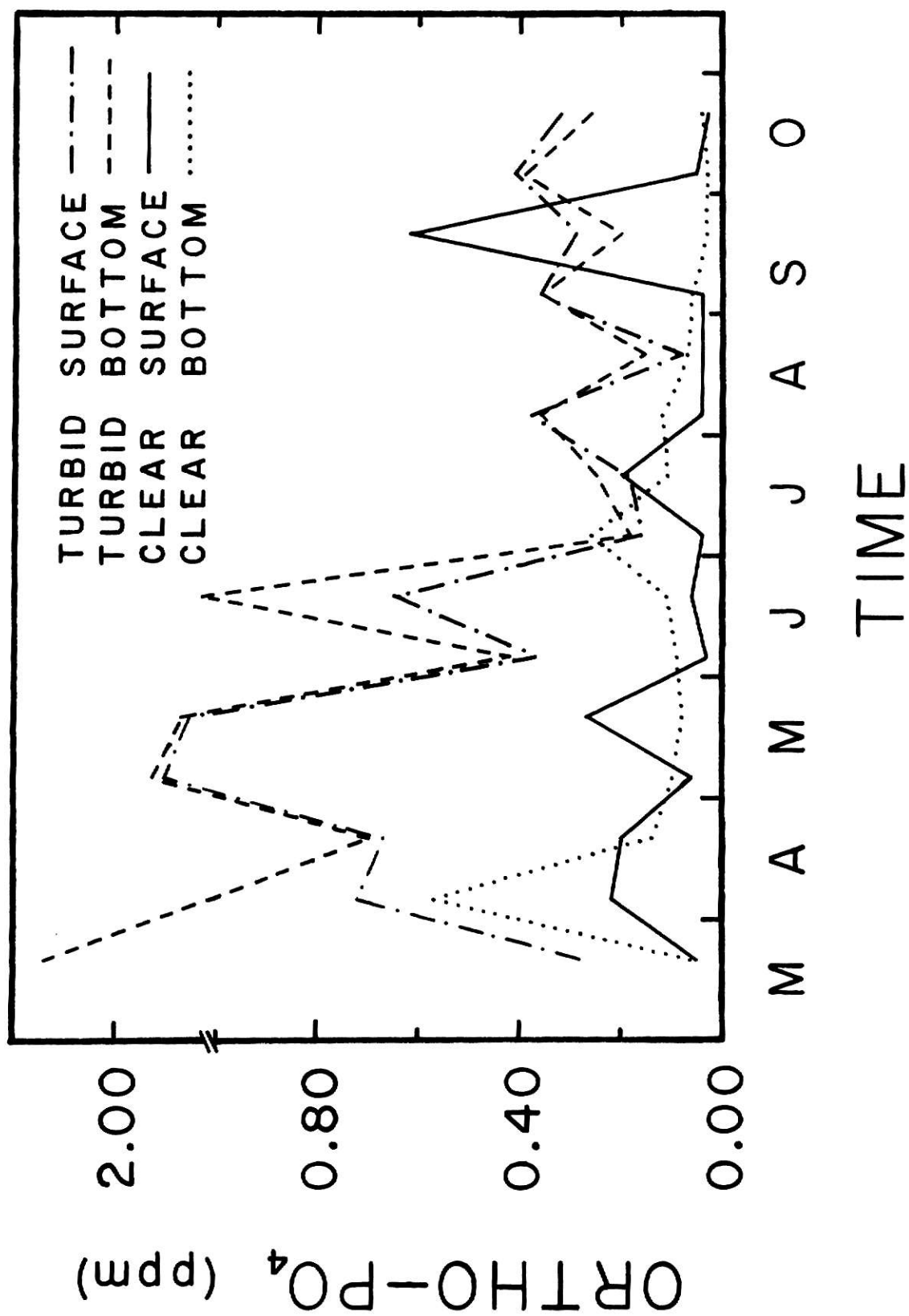


Figure 12

Figure 13. Average chlorophyll-a concentrations (mg./m^3) for the clear and turbid farm ponds located in Riley and Pottawatomie Counties, Kansas.

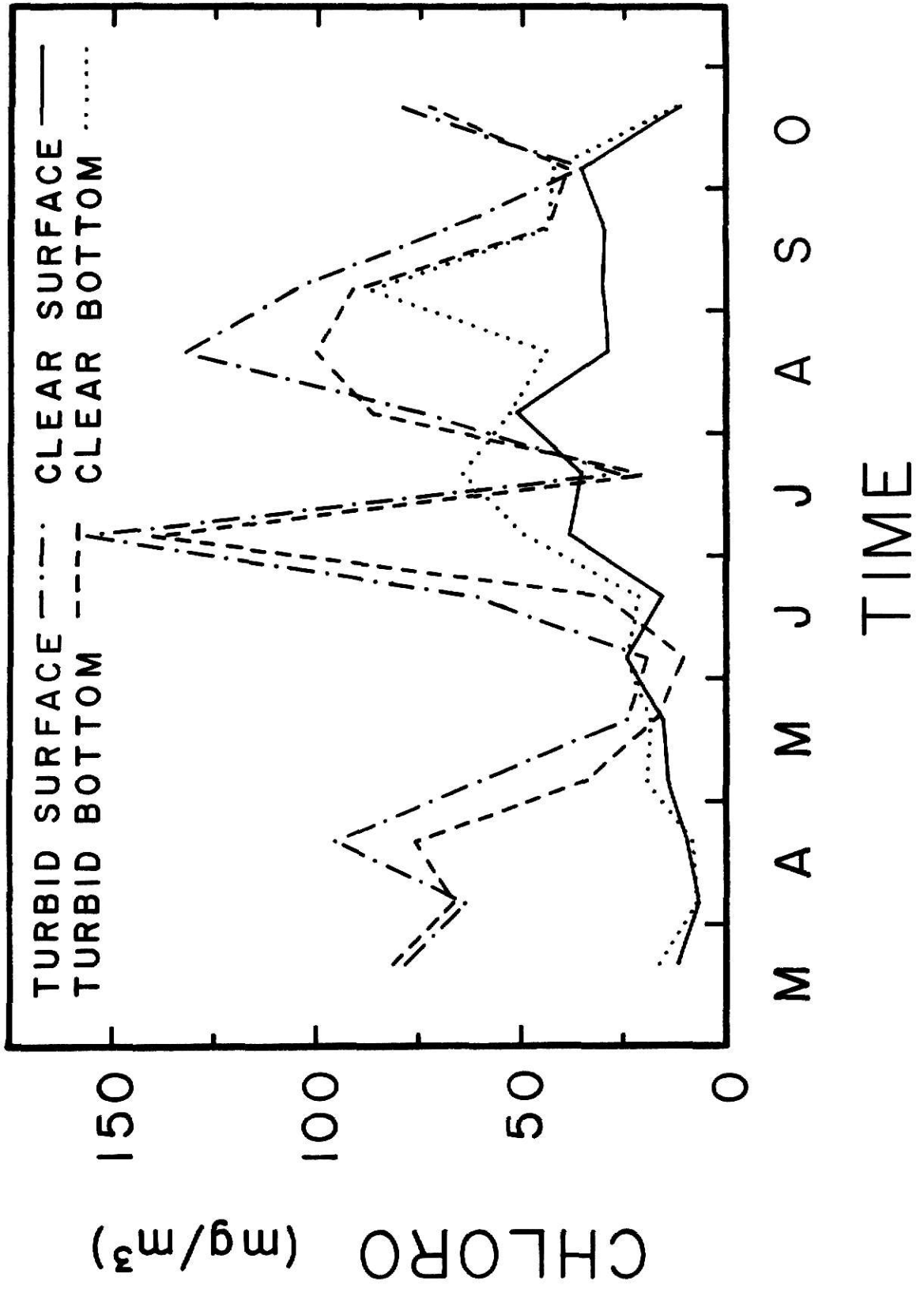


Figure 13

Figure 14. Average density (organisms/liter) for the rotifers (Filinia longiseta, Asplanchna sp., and Keratella cochlearis) in the clear and turbid ponds located in Riley and Pottawatomie Counties, Kansas.

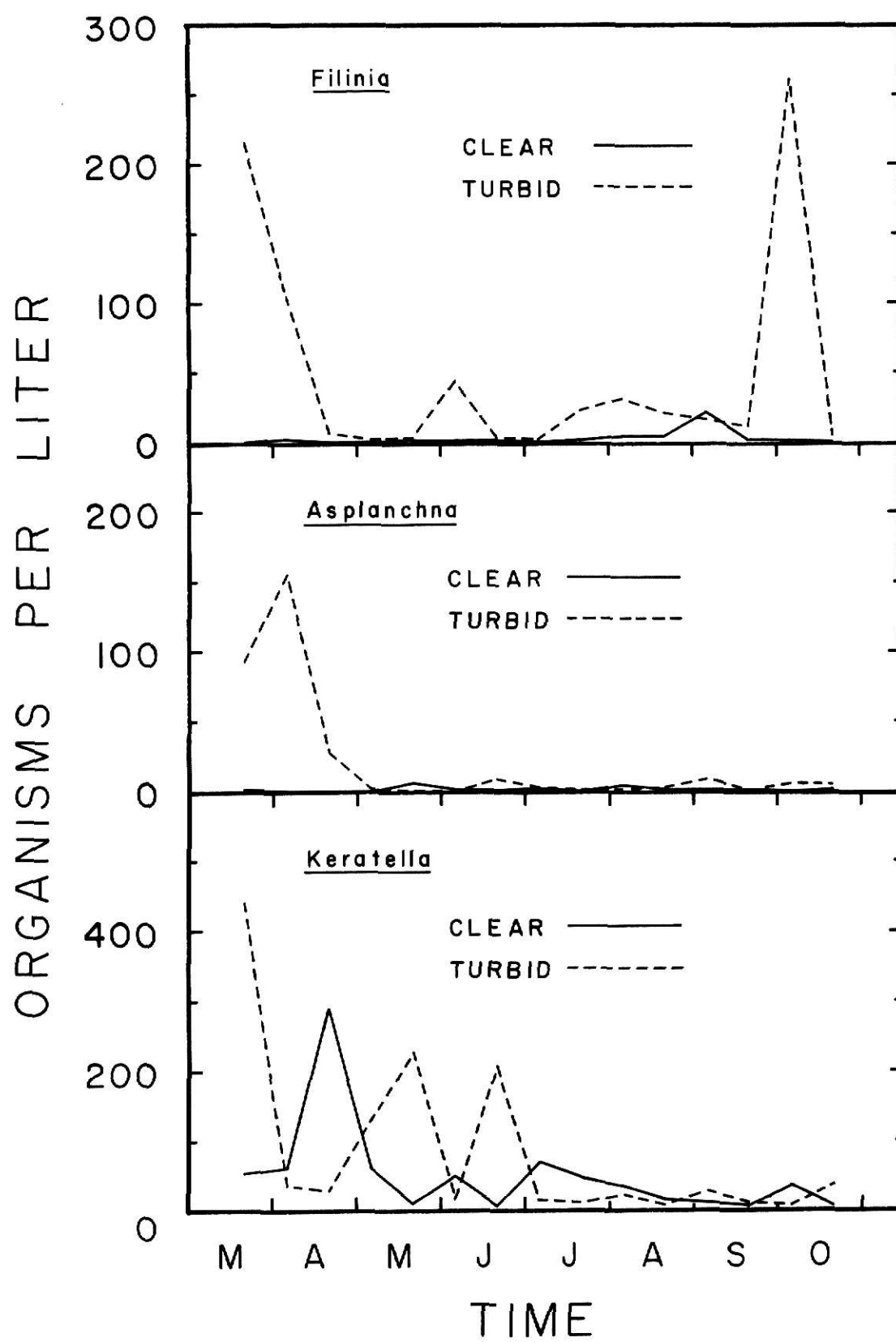


Figure 14

Figure 15. Average density (organisms/liter) for the copepods (Cyclops sp.,
Diaptomus sp., and nauplii) in the clear and turbid ponds
located in Riley and Pottawatomie Counties, Kansas.

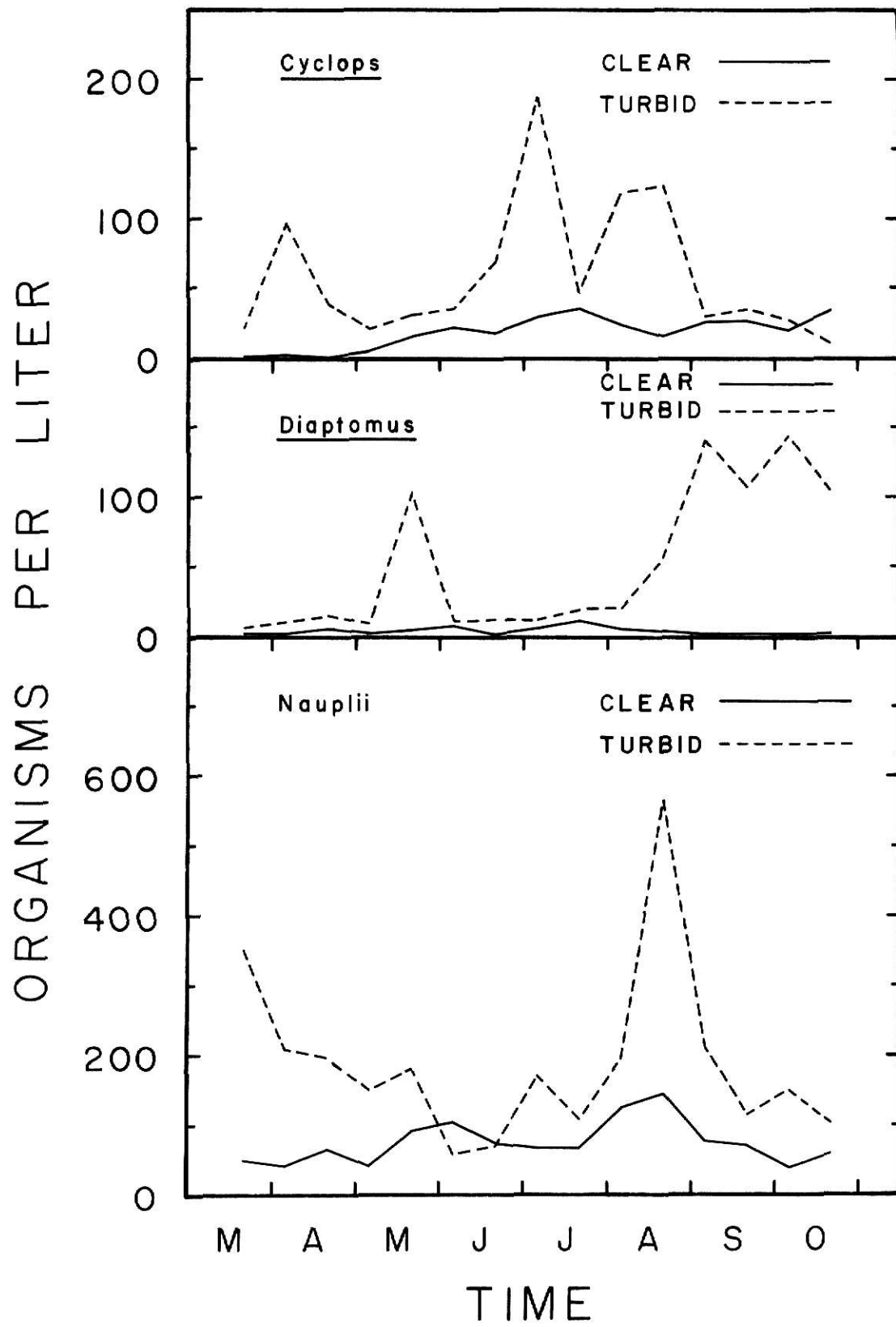


Figure 15

Figure 16. Average density (organisms/liter) for the cladocerans
(Daphnia sp., Ceriodaphnia lacustris, and Bosmina longirostris)
in the clear and turbid ponds located in Riley and Pottawatomie
Counties, Kansas.

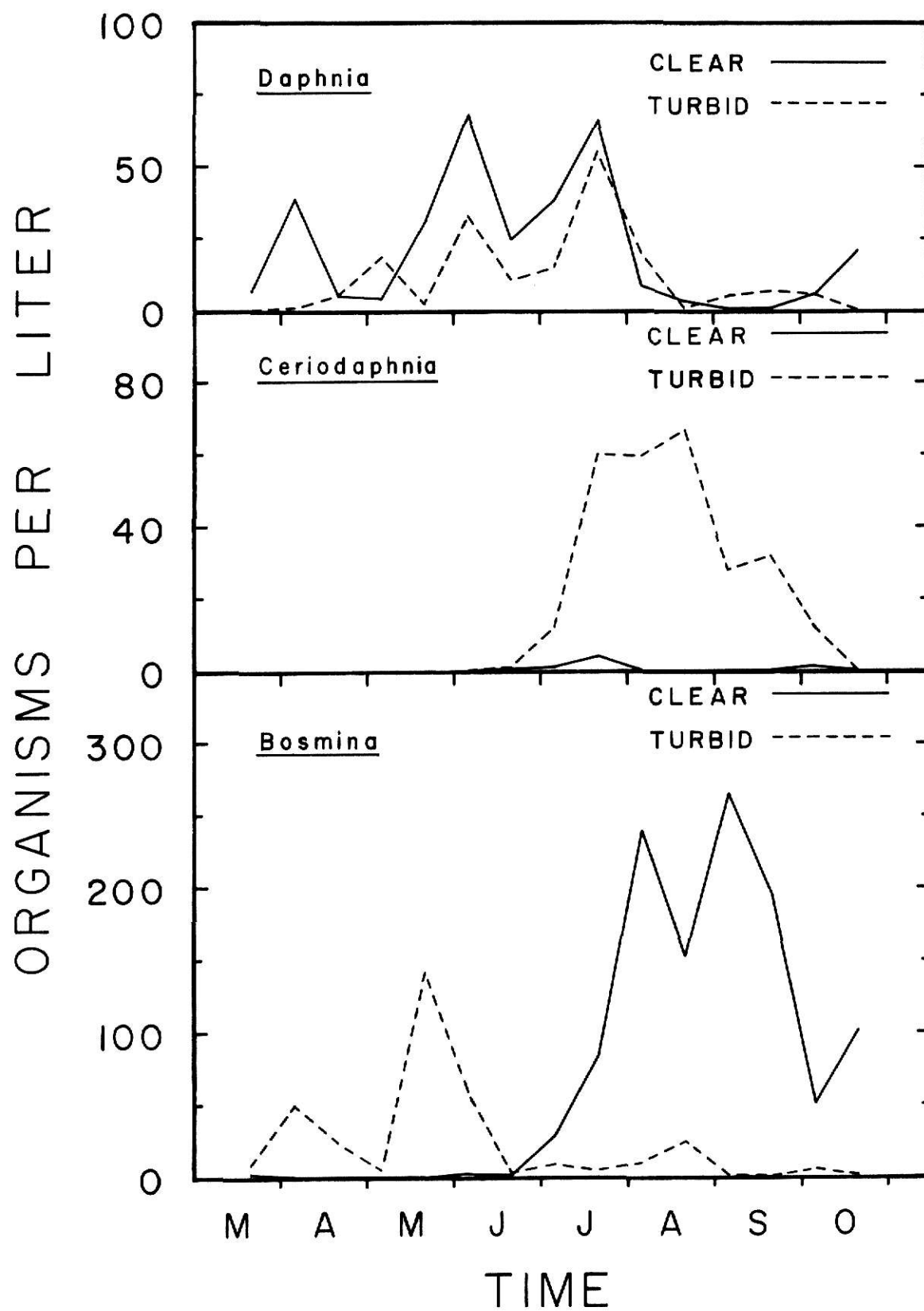


Figure 16

Figure 17. Average density (organisms/liter) for the cladocerans (Diaphanosoma brachyurum and Macrothrix laticornis) and total zooplankton in the clear and turbid farm ponds located in Riley and Pottawatomie Counties, Kansas.

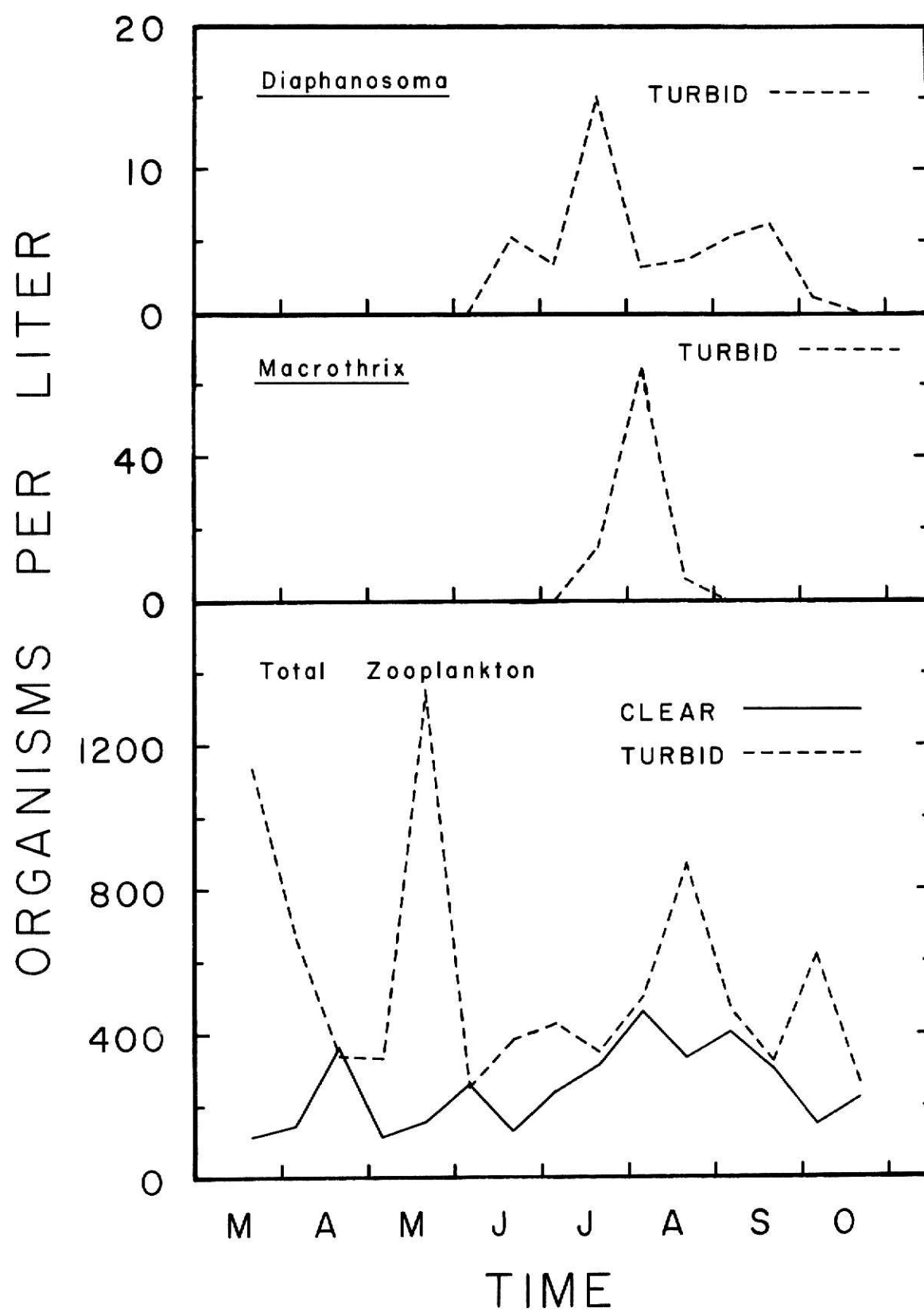
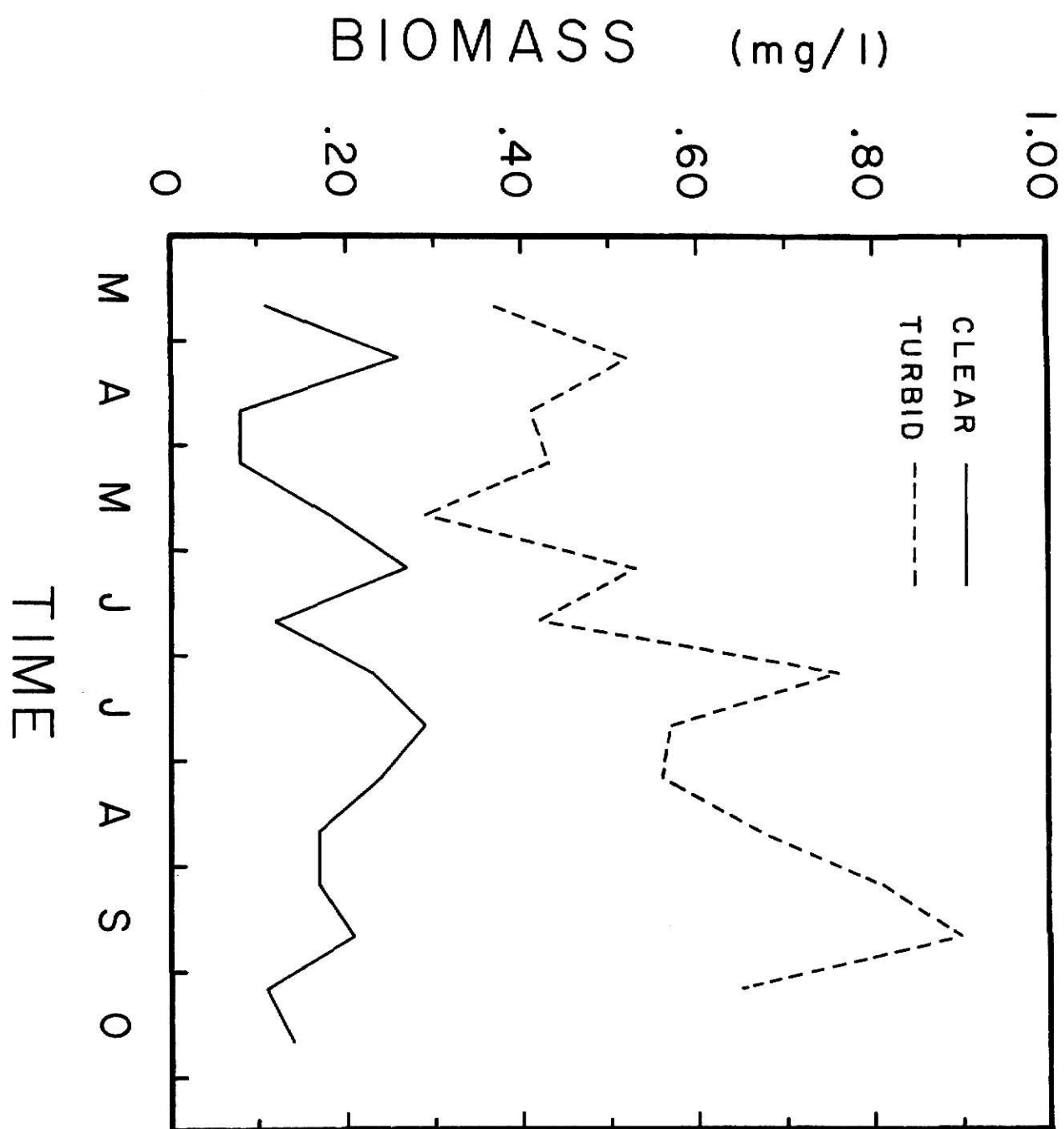


Figure 17

Figure 18. Average biomass (mg./liter) for the zooplankton occurring in the clear and turbid farm ponds located in Riley and Pottawatomie Counties, Kansas.



LITERATURE CITED

- Ahlstrom, E. H. 1934. A quantitative study of Rotatoria in Terwilliger's Pond, Put-in-Bay, Ohio. Ohio State Univ. Nat. Hist. Surv. 6: 1-36.
- American Public Health Association. 1965. Standard Methods for the Examination of Water and Wastewater, 12th ed. Amer. Pub. Health Assoc., Inc., New York. 769 p.
- Armitage, K. B. 1961. Species composition and seasonal distribution of limnetic crustacean zooplankton of northeastern Kansas. Trans. Kan. Acad. Sci. 64: 27-35.
- Bennett, G. W. 1971. Management of Lakes and Ponds. 2nd Edition. Van Nostrand Reinhold Co., New York. 375 p.
- Butler, J. L. 1962. Temperature relations in shallow turbid ponds. Proc. Okla. Acad. Sci. 43: 90-95.
- Edmondson, W. T. (ed.). 1959. Freshwater Biology. 2nd Edition. John Wiley and Sons, New York. 1248 p.
- Fryer, G. 1957. The food of some freshwater cyclopoid copepods and its ecological significance. J. Animal Ecol. 26: 263-286.
- Irwin, W. H. and F. J. Claffey. 1968. Soil turbidity, light penetration and plankton populations in Oklahoma ponds and lakes. Proc. Okla. Acad. Sci. 47: 72-81.
- Leonard, A. B. and L. H. Ponder. 1949. Crustacea in eastern Kansas. Trans. Kan. Acad. Sci. 52: 168-204.
- Novak, M. A. 1969. Seasonal variation of particulate organic matter in Tuttle Creek Reservoir. Master's Thesis. Kansas State University. 42 p.
- Parsons, T. R. and J. D. H. Strickland. 1963. Discussion of spectrophotometric determination of marine-plant pigments, with revised equations for ascertaining chlorophylls and carotenoids. J. Mar. Res. 21(2): 155-163.
- Pennak, R. W. 1953. Freshwater Invertebrates of the United States. The Ronald Press Co., New York. 769 p.
- _____. 1957. Species composition of limnetic zooplankton communities. Limnol. Oceanogr. 2(3): 222-232.
- Prophet, C. W. 1964. Some limnological features of Lyon County State Lake during reflooding. Trans. Kan. Acad. Sci. 67(4): 676-685.

- _____. 1966. Limnology of John Redmond Reservoir, Kansas. Emporia State Research Studies. 15: 5-27.
- _____, T. F. Andrews, and C. E. Goulden. 1959. Annotated checklist of the Cladocera and Copepoda of Lyon County, Kansas. Southwest. Nat. 4(4): 185-194.
- _____, and S. Waite. 1974. A species list of Cladocera and Copepoda. Trans. Kan. Acad. Sci. 77(1): 42-47.
- Richards, F. A. and T. G. Thompson. 1952. The estimation and characterization of plankton populations by pigment analysis. II. A spectrophotometric method for the estimation of plankton pigments. J. Mar. Res. 2: 156-172.
- Ruttner, F. 1963. Fundamentals of Limnology. 3rd Edition. University of Toronto Press, Canada. 295 p.
- Sawyer, C. N. 1952. Stream pollution. Some new aspects of phosphates in relation to lake fertilization. Sewage and Industrial Wastes. 24: 768-776.
- Schultz, V. 1952. A limnological study of an Ohio farm pond. Ohio J. Sci. 52(5): 267-285.
- Smrcek, J. C. 1970. A limnological study of three farm ponds in Douglas County, Kansas. Trans. Kan. Acad. Sci. 73: 181-226.
- Strickland, J. D. H. and T. R. Parsons. 1960. A manual of sea water analysis. Fish. Res. Bd. Can. Bull. No. 125: 113-121.
- Surber, T. and T. A. Olson. 1936. Some observations on Minnesota fish ponds. Trans. Amer. Fish. Soc. 66: 104-127.
- Swingle, H. S. 1947. Experiments on pond fertilization. Ala. Poly. Inst. Agr. Expt. Sta. Bull. 264: 1-34.
- Taylor, M. W. 1971. Zooplankton ecology of a Great Plains Reservoir. Master's Thesis. Kansas State University. 85 p.
- Tiemeier, O. W. 1966. Kansas farm ponds. Kan. St. Univ. Agr. Exp. Sta. Bull. 488: 1-64.
- _____, and J. B. Elder. 1957. Limnology of Flint Hills farm ponds. Trans. Kan. Acad. Sci. 60(4): 379-392.
- _____, and R. B. Moorman. 1957. Limnological observations on some Flint Hills farm ponds. Trans. Kan. Acad. Sci. 60(2): 167-173.
- Wallen, I. E. 1951. The relationship of turbidity to temperature of some farm ponds. Proc. Okla. Acad. Sci. 32: 20-26.
- _____. 1955. Some limnological considerations in the productivity of Oklahoma farm ponds. J. Wildl. Manag. 19: 450-462.

- Ward, J. 1955. A description of a new zooplankton counter.
Quart. J. Microsc. Soc. 96: 371-373.
- Welch, P. S. 1948. *Limnological methods*. The Blakiston Co.,
Philadelphia. 381 p.
- Wiebe, A. H. 1930. Investigations on plankton production in fish
ponds. Bull. U. S. Bur. Fish. (Doc. 1082). 46: 137-176.
- Willis, H. 1959. Some limnological conditions of Turkey Creek and
two ponds near Shawnee, Kansas from June 8, 1957, to August 16,
1957. Trans. Kan. Acad. Sci. 62: 20-27.
- Zeller, H. D. 1953. Nitrogen and phosphorus concentrations in
fertilized and unfertilized farm ponds in central Missouri.
Trans. Amer. Fish. Soc. 82: 281-288.

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APPENDIX

APPENDIX I

DETERMINATION OF ORGANIC (OXIDIZABLE) MATTER AS CARBON

(A Modified Method)*

The modified method (Taylor, 1971) involves the utilization of a new filter now on the market made of pure glass and eliminates the use of magnesium carbonate coated AA Millipore filters which interfere with the dichromate oxidation. Laboratory investigations have shown that the pure glass fiber filters do not interrupt the oxidation process, and their efficiency is comparable to a AA Millipore filter (pore size = 0.45 microns). The ultra-fine sintered glass filter was also no longer needed in the modified method.

Laboratory Materials

glass fiber filters	100 ml. volumetric flasks
filtering apparatus (1" heads)	sulfuric acid (s. g. = 1.82)
spectrophotometer	glucose
20 ml. beakers (with glass covers)	potassium dichromate

Special Reagent

Sulfuric acid-dichromate oxidant: Dissolve 4.84 g of potassium dichromate, $K_2Cr_2O_7$, in 20 ml. of distilled water. Add a little of this solution at a time to about 500 ml. of concentrated sulfuric acid in a 1 liter volumetric flask. Cool the mixture to room temperature and make to volume with more concentrated acid. It will be stable indefinitely if stored in a glass-stoppered bottle protected from the dust.

Cleaning of Glassware

It is of utmost importance that all the glassware used in this

*Original unmodified method by Strickland and Parsons (1960).

method be cleaned in hot sulfuric acid-dichromate cleaning solution and stored in a desiccator or other dust free container where contamination is impossible. After use it is adequate to rinse the glassware several times with distilled water.

Calibration

Standard glucose solution: Dissolve 7.50 g of pure glucose in distilled water and make to volume of 100 ml. This solution is stable indefinitely if stored in a refrigerator, but must be discarded if any turbidity develops. For use dilute 10.0 ml. of the concentrated solution to 1 liter with distilled water and use within a day of preparation. The dilute solution is used for calibration, and 1 ml. contains 300 micrograms of carbon.

Make the following four standard solutions from the dilute glucose solution using acid washed glassware:

Solution	Dilute Glucose, ml	Water, ml	$\mu\text{gC/ml}$
1	100	0	300
2	25	75	75
3	10	90	30
4	3	97	9

Place glass filters in nine clean 20 ml. beakers and then add the following:

Beaker	Solution	Amount, ml	Water, ml	Oxidant, ml	μgC
1	1	2	0	2	600
2	1	1	1	2	300
3	2	2	0	2	150
4	2	1	1	2	75
5	3	2	0	2	60
6	3	1	1	2	30
7	4	1	1	2	9
b ₁	0	0	2	2	0
b ₂	0	0	2	2	0

Place the coverglasses over the beakers and heat the contents for 60 minutes at 100 to 110° C. Remove from the oven and cool to room temperature; then pour each solution in a separate 100 ml. volumetric

flask and make to volume, rinsing the beaker thoroughly. Fill half of a spectrophotometer cuvette with each of the blank solutions (beakers b_1 and b_2) and read the extinction of each standard solution against the blank and record the extinction, E . If any turbidity is visible the solution should be transferred from the spectrophotometer cell to a centrifuge tube and cleared by centrifugation at high speed for about 5 minutes. Multiply the extinction, E , by 1.1 to correct for the extinction of trivalent chromium to obtain E_c . Fit a linear regression to the line and obtain the value for the constants (a and b) in the equation:

$$\mu\text{gC} = a + b(E_c)$$

The value for a should be close to 0 and b should be about 4550. This equation is used to calculate the μgC occurring in a sample after determining the E_c for the sample using the analytical procedure.

Experimental Procedure

The sample used for analysis may be stored in a polyethylene bottle in a cool, dark place but not for more than 4 or 5 hours to minimize error due to bacterial activity. The water should first be strained through a medium mesh plankton net to remove the larger zooplankters without loosing plant cells or detrital particles. Filter a suitable volume of water using a glass fiber filter soas to obtain between 0 and 300 μgC ; for most freshwaters 50 to 250 ml. is sufficient volume to filter. This is necessary because the equation that was obtained is not valid for values outside this range. After filtering, the filter funnel must be washed thoroughly with distilled water and sucked dry. Remove the filter from the filtering apparatus with a forceps and place in the 20 ml. beaker. Add 2 ml. of distilled water

and 2 ml. of sulfuric acid-dichromate oxidant to the beaker, cover, and heat in an oven for 60 minutes at 100 to 110° C. The time is not critical but is a safe maximum for complete oxidation. There is nothing to gain by prolonging the heating process, and the chances of contamination are increased. Take the beakers from the oven and cool to room temperature; then pour the contents of the beakers into separate 100 ml. volumetric flasks, rinse thoroughly, and make to volume of 100 ml. with distilled water. Two blanks must be processed, just as the rest of the samples, except no filtrate. Fill a cuvette half from each blank, and read the extinction of the samples against the blank. Multiply the extinction, E , by 1.1 to obtain E_c . If E_c exceeds 0.8 repeat the sample filtering a smaller volume of water. It is also advisable to repeat the procedure on samples with a reading less than 0.1 using a larger volume of water. The value obtained for E_c is inserted in the equation derived previously to find the μgC in the sample. Divide this value by the volume of water filtered in liters to obtain mgC/m^3 in the water.

APPENDIX II

Statistical analysis of variance for the physical, chemical, and biological variables measured during the sampling period from March, 1974 to October, 1974, are presented on the following pages. The mean square for ponds was used as the denominator when calculating the "F" statistic for types of ponds. The error term was used as the denominator in the remaining calculations. The probability column in the analysis of variance table represents the probability of there being differences between types, differences due to the sampling time, and differences caused by the effect of time on the types. The probability level indicating a significant difference was set at 0.20. The significance levels were denoted as the following:

- * Statistically significant at the 0.01 level.
- ** Statistically significant at the 0.05 level.
- *** Statistically significant at the 0.10 level.
- **** Statistically significant at the 0.15 level.
- ***** Statistically significant at the 0.20 level.

Table 1. Analysis of variance of water level obtained from the three turbid and the three clear farm ponds.

Source	Degrees of Freedom	Mean Square	Probability
Pond Type	1	2125.0713	
Ponds	4	37.2708	0.00000*
Date	13	99.4765	0.00000*
Pond Type X Date	13	47.7394	0.00000*
Error	52	5.7659	
Total	83		

Table 2. Analysis of variance of surface water turbidity from the three turbid and the three clear farm ponds.

Source	Degrees of Freedom	Mean Square	Probability
Pond Type	1	235214.4375	
Ponds	4	15637.1797	0.020 **
Date	13	6531.0313	0.26824
Pond Type X Date	13	4997.3594	0.49909
Error	52	5192.0234	
Total	83		

Table 3. Analysis of variance of bottom water turbidity from the three turbid and the three clear farm ponds.

Source	Degrees of Freedom	Mean Square	Probability
Pond Type	1	141614.1250	0.19000*****
Ponds	4	49816.0938	
Date	13	13537.0977	0.28331
Pond Type X Date	13	5260.8438	0.92642
Error	52	10969.8477	
Total	83		

Table 4. Analysis of variance of surface water temperature from the three turbid and the three clear farm ponds.

Source	Degrees of Freedom	Mean Square	Probability
Pond Type	1	0.6698	0.75000
Ponds	4	5.1474	
Date	13	271.9541	0.00000*
Pond Type X Date	13	0.9950	0.96296
Error	52	3.2786	
Total	83		

Table 5. Analysis of variance of bottom water temperature from the three turbid and the three clear farm ponds.

Source	Degrees of Freedom	Mean Square	Probability
Pond Type	1	1.4404	0.85000
Ponds	4	19.4853	
Date	13	162.2588	0.00000*
Pond type X Date	13	0.8553	0.96896
Error	52	2.2248	
Total	83		

Table 6. Analysis of variance of surface water particulate organic matter from the three turbid and the three clear farm ponds.

Source	Degrees of Freedom	Mean Square	Probability
Pond Type	1	60716703.9999	0.29000
Ponds	4	37637888.0000	
Date	13	2821300.0000	0.15203*****
Pond Type X Date	13	1745926.0000	0.53588
Error	52	1890557.0000	
Total	83		

Table 7. Analysis of variance of bottom water particulate organic matter from the three turbid and the three clear farm ponds.

Source	Degrees of Freedom	Mean Square	Probability
Pond Type	1	32038224.0000	0.43000
Ponds	4	38212736.0000	
Date	13	2238782.0000	0.18211*****
Pond Type X Date	13	1651712.0000	0.42320
Error	52	1576658.0000	
Total	83		

Table 8. Analysis of variance of surface water specific conductivity from the three turbid and the clear farm ponds.

Source	Degrees of Freedom	Mean Square	Probability
Pond Type	1	166518.9375	0.24000
Ponds	4	86215.3750	
Date	13	3136.7974	0.04763**
Pond Type X Date	13	2077.5972	0.25537
Error	52	1624.2632	
Total	83		

Table 9. Analysis of variance of bottom water specific conductivity from the three turbid and the clear farm ponds.

Source	Degrees of Freedom	Mean Square	Probability
Pond Type	1	169021.9375	0.31000
Ponds	4	111190.1875	
Date	13	3718.1194	0.04724**
Pond Type X Date	13	1645.9939	0.63219
Error	52	1994.9363	
Total	83		

Table 10. Analysis of variance of surface water total alkalinity from the three turbid and the three clear farm ponds.

Source	Degrees of Freedom	Mean Square	Probability
Pond Type	1	56783.9883	0.19000*****
Ponds	4	19937.6406	
Date	13	2366.8628	0.00000 *
Pond Type X Date	13	400.6147	0.40821
Error	52	376.0283	
Total	83		

Table 11. Analysis of variance of bottom water total alkalinity from the three turbid and the three clear farm ponds.

Source	Degrees of Freedom	Mean Square	Probability
Pond Type	1	59095.0117	0.22000
Ponds	4	25433.1875	
Date	13	2121.2957	0.00000*
Pond Type X Date	13	434.3545	0.36451
Error	52	387.9180	
Total	83		

Table 12. Analysis of variance of surface water dissolved oxygen from the three turbid and the three clear farm ponds.

Source	Degrees of Freedom	Mean Square	Probability
Pond Type	1	2.8233	0.48000
Ponds	4	4.4524	
Date	13	15.8600	0.00000*
Pond Type X Date	13	2.9884	0.29123
Error	52	2.4708	
Total	83		

Table 13. Analysis of variance of bottom water dissolved oxygen from the three turbid and the three clear farm ponds.

Source	Degrees of Freedom	Mean Square	Probability
Pond Type	1	6.7433	0.60000
Ponds	4	17.9104	
Date	13	69.4400	0.00000*
Pond Type X Date	13	5.2315	0.28423
Error	52	4.2442	
Total	83		

Table 14. Analysis of variance of surface water free carbon dioxide from the three turbid and the three clear farm ponds.

Source	Degrees of Freedom	Mean Square	Probability
Pond Type	1	131.2499	0.34000
Ponds	4	96.2499	
Date	13	32.2170	0.00000*
Pond Type X Date	13	12.4294	0.06138***
Error	52	6.7627	
Total	83		

Table 15. Analysis of variance of bottom water free carbon dioxide from the three turbid and the three clear farm ponds.

Source	Degrees of Freedom	Mean Square	Probability
Pond Type	1	82.0120	0.53000
Ponds	4	172.3809	
Date	13	43.6455	0.00029*
Pond Type X Date	13	18.0631	0.12544****
Error	52	11.5218	
Total	83		

Table 16. Analysis of variance of surface water nitrate nitrogen from the three turbid and the three clear farm ponds.

Source	Degrees of Freedom	Mean Square	Probability
Pond Type	1	0.1100	
Ponds	4	0.2637	0.58000
Date	13	0.3047	0.00729*
Pond Type X Date	13	0.1126	0.49883
Error	52	0.1169	
Total	83		

Table 17. Analysis of variance of bottom water nitrate nitrogen from the three turbid and the three clear farm ponds.

Source	Degrees of Freedom	Mean Square	Probability
Pond Type	1	0.8805	
Ponds	4	0.1723	0.09000***
Date	13	0.6189	0.00595*
Pond Type X Date	13	0.3581	0.13128****
Error	52	0.2310	
Total	83		

Table 18. Analysis of variance of surface water orthophosphate from the three turbid and the three clear farm ponds.

Source	Degrees of Freedom	Mean Square	Probability
Pond Type	1	3.1824	
Ponds	4	1.8865	0.28000
Date	13	0.3165	0.31543
Pond Type X Date	13	0.2898	0.39127
Error	52	0.2668	
Total	83		

Table 19. Analysis of variance of bottom water orthophosphate from the three turbid and the three clear farm ponds.

Source	Degrees of Freedom	Mean Square	Probability
Pond Type	1	8.7043	
Ponds	4	4.4520	0.24000
Date	13	0.8330	0.24117
Pond Type X Date	13	0.8245	0.24879
Error	52	0.6390	
Total	83		

Table 20. Analysis of variance of surface water hydrogen-ion concentration from the three turbid and the clear farm ponds.

Source	Degrees of Freedom	Mean Square	Probability
Pond Type	1	1.8305	
Ponds	4	0.4738	0.14000****
Date	13	0.6936	0.00000*
Pond Type X Date	13	0.1338	0.24398
Error	52	0.1030	
Total	83		

Table 21. Analysis of variance of bottom water hydrogen-ion concentration from the three turbid and the clear farm ponds.

Source	Degrees of Freedom	Mean Square	Probability
Pond Type	1	1.7719	
Ponds	4	1.2648	0.33000
Date	13	0.3310	0.00002*
Pond Type X Date	13	0.0892	0.23967
Error	52	0.0672	
Total	83		

Table 22. Analysis of variance of surface water chlorophyll_a from the three turbid and the three clear farm ponds.

Source	Degrees of Freedom	Mean Square	Probability
Pond Type	1	52489.5664	0.43000
Ponds	4	57968.0469	
Date	13	2798.6499	0.35177
Pond Type X Date	13	2327.1604	0.52186
Error	52	2471.0500	
Total	83		

Table 23. Analysis of variance of bottom water chlorophyll_a from the three turbid and the three clear farm ponds.

Source	Degrees of Freedom	Mean Square	Probability
Pond Type	1	16024.7227	0.59000
Ponds	4	40587.4844	
Date	13	3493.2236	0.15962*****
Pond Type X Date	13	2187.0483	0.55266
Error	52	2401.5657	
Total	83		

Table 24. Analysis of variance of Filinia longiseta from the three turbid and the three clear farm ponds.

Source	Degrees of Freedom	Mean Square	Probability
Pond Type	1	53570.2891	0.02000* *
Ponds	4	3524.5273	
Date	13	10343.0469	0.69793
Pond Type X Date	13	10809.6992	0.66417
Error	52	13634.1289	
Total	83		

Table 25. Analysis of variance of Asplanchna sp. from the three turbid and the three clear farm ponds.

Source	Degrees of Freedom	Mean Square	Probability
Pond Type	1	9202.2656	0.36000
Ponds	4	7285.6641	
Date	13	3102.1567	0.21698
Pond Type X Date	13	3192.5642	0.19731*****
Error	52	2301.3496	
Total	83		

Table 26. Analysis of variance of Keratella cochlearis from the three turbid and the three clear farm ponds.

Source	Degrees of Freedom	Mean Square	Probability
Pond Type	1	20645.5195	0.56000
Ponds	4	46169.6406	
Date	13	28515.4688	0.70562
Pond Type X Date	13	35011.8867	0.53751
Error	52	37982.0938	
Total	83		

Table 27. Analysis of variance of Cyclops sp. from the three turbid and the three clear farm ponds.

Source	Degrees of Freedom	Mean Square	Probability
Pond Type	1	44518.7461	0.27000
Ponds	4	26249.1719	
Date	13	4380.1953	0.37035
Pond Type X Date	13	3546.0945	0.55811
Error	52	3938.2776	
Total	83		

Table 28. Analysis of variance of Diaptomus sp. from the three turbid and the three clear farm ponds.

Source	Degrees of Freedom	Mean Square	Probability
Pond Type	1	40208.3125	
Ponds	4	6319.2695	0.07000***
Date	13	3916.1501	0.67081
Pond Type X Date	13	4317.9414	0.59096
Error	52	4981.5195	
Total	83		

Table 29. Analysis of variance of Copepoda nauplii from the three turbid and the three clear farm ponds.

Source	Degrees of Freedom	Mean Square	Probability
Pond Type	1	297856.4375	
Ponds	4	164380.3750	0.25000
Date	13	31117.5273	0.36495
Pond Type X Date	13	21554.4805	0.68161
Error	52	27805.0352	
Total	83		

Table 30. Analysis of variance of Daphnia sp. from the three turbid and the three clear farm ponds.

Source	Degrees of Freedom	Mean Square	Probability
Pond Type	1	1599.0613	
Ponds	4	3118.1191	0.52000
Date	13	1949.5835	0.05086**
Pond Type X Date	13	430.1003	0.95529
Error	52	1022.2075	
Total	83		

Table 31. Analysis of variance of Ceriodaphnia lacustris from the three turbid and the three clear farm ponds.

Source	Degrees of Freedom	Mean Square	Probability
Pond Type	1	7467.4102	
Ponds	4	5653.5078	0.35000
Date	13	1007.0212	0.29977
Pond Type X Date	13	944.1394	0.35386
Error	52	832.8852	
Total	83		

Table 32. Analysis of variance of Bosmina longirostris from the three turbid and the three clear farm ponds.

Source	Degrees of Freedom	Mean Square	Probability
Pond Type	1	48542.5430	
Ponds	4	58172.0781	0.43000
Date	13	12688.8164	0.59161
Pond Type X Date	13	20658.0117	0.18658*****
Error	52	14650.0195	
Total	83		

Table 33. Analysis of variance total zooplankton from the three turbid and the three clear farm ponds.

Source	Degrees of Freedom	Mean Square	Probability
Pond Type	1	2222241.9999	
Ponds	4	476002.2500	0.09800 ***
Date	13	146866.6875	0.90798
Pond Type X Date	13	222583.1250	0.68317
Error	52	287716.3125	
Total	83		

Table 34. Analysis of variance of Zooplankton Biomass from the three turbid and the three clear farm ponds.

Source	Degrees of Freedom	Mean Square	Probability
Pond Type	1	3.8923	0.16000*****
Ponds	4	1.2697	
Date	13	0.0714	0.28690
Pond Type X Date	13	0.0522	0.55988
Error	52	0.0581	
Total	83		

APPENDIX III

The following four supplementary tables give the maximum, minimum, and mean values for the physical, chemical, and biological variables that were obtained when sampling the clear and turbid farm ponds from March through mid-October, 1974.

Table 1. Maximum, minimum, and mean values for the physical, chemical, and biological variables obtained from water samples taken from surface and bottom water in the three clear (C) ponds.

Pond	Secchi Disc (cm)	Turb. (JTU)	Temp. (°C.)	Part. Org. Matter (mgC/m ³)	Conduct. (mmhos/cm)	Diss. Oxyg. (ppm)	pH	CO ₂ (ppm)	T. alk. as ppm CaCO ₃	Ortho-phos. (ppm)	NO ₃ -N (ppm)	Chlor _{3a} (mg/m ³)
P-1	TOP	Max	30.2	2930	440	12.0	8.7	6	216	1.80	0.60	45.1
		Mini	4.7	210	330	6.2	7.5	0	123	0.02	0.25	7.5
		Mean	20.9	1420	384	8.4	8.2	1.9	176	0.22	0.38	22.3
P-1	BOTTOM	Max	23.9	1890	480	11.8	8.7	12	225	0.14	0.75	57.4
		Mini	4.6	140	340	0.6	7.5	0	141	0.01	0.30	10.6
		Mean	17.1	1450	407	5.0	7.9	5.6	188	0.04	0.44	32.6
P-2	TOP	Max	28.7	1860	575	12.8	8.7	5	261	0.15	0.69	83.1
		Mini	4.6	140	340	5.4	7.8	0	123	0.02	0.20	4.1
		Mean	20.4	760	422	8.4	8.3	1.3	195	0.05	0.42	18.5
P-2	BOTTOM	Max	24.5	2920	560	11.4	8.7	10	261	1.50	0.65	101.4
		Mini	4.4	140	350	0.4	7.6	0	159	0.00	0.23	5.8
		Mean	17.7	1030	434	5.9	8.1	3.7	201	0.16	0.48	24.0
P-3	TOP	Max	32.0	2750	300	12.6	8.6	9	123	0.50	1.10	99.9
		Mini	10.1	50	190	5.4	7.4	0	66	0.04	0.22	0.6
		Mean	21.8	1040	224	8.6	7.9	3	96	0.14	0.62	31.2
P-3	BOTTOM	Max	20.1	5830	315	12.0	8.3	14	135	0.68	1.10	192.2
		Mini	6.0	80	96	0.0	6.7	0	39	0.04	0.35	0.6
		Mean	15.5	1850	214	3.7	7.4	8.6	92	0.19	0.66	46.2

Table 2. Maximum, minimum, and mean values for the physical, chemical, and biological variables obtained from water samples taken from surface and bottom water in the three turbid (T) ponds.

Pond	Secchi		Turb.	Temp.	Part. Org.	Conduct.	Diss.	CO ₂		T. alk.	Ortho-	NO ₃ -N	Chlor _a
	Disc	(cm)	(JTU)	(°C.)	(mgC/m ³)	(mmhos/cm)	Oxyg.	pH	(ppm)	ppm as CaCO ₃	phos. (ppm)	(ppm)	(mg/m ³)
F-1	TOP	90	240	28.3	2200	330	11.8	8.6	6	132	0.70	1.30	32.2
	Mini	15	6	4.3	410	130	6.0	7.0	0	75	0.04	0.00	4.0
	Mean	38	81	21.6	1020	251	7.9	8.0	2.9	113	0.21	0.46	16.8
F-1	BOTTOM	148	148	20.5	1760	330	11.8	8.6	12	141	2.70	4.30	26.0
	Mini	0	0	3.9	30	125	0.0	7.1	0	69	0.03	0.20	8.0
	Mean	61	61	15.2	890	257	3.7	7.6	7.1	118	0.52	0.76	12.7
F-2	TOP	35	290	29.2	11340	380	14.0	9.7	23	144	3.60	2.40	498.5
	Mini	10	68	4.0	800	250	2.8	6.8	0	57	.17	0.05	7.5
	Mean	23	142	21.2	5370	292	9.1	7.7	8.7	101	1.12	0.71	173.4
F-2	BOTTOM	325	325	23.2	9910	390	13.2	8.4	29	147	6.80	2.20	399.5
	Mini	55	55	3.6	730	250	0.0	6.8	0	63	0.20	0.05	5.6
	Mean	142	142	17.4	5270	303	3.6	7.3	12.6	105	1.67	0.82	144.5
F-3	TOP	50	550	28.1	4290	260	12.8	8.6	5	120	1.90	1.50	40.8
	Mini	10	42	1.7	1090	142	7.0	7.3	0	60	0.02	0.01	10.7
	Mean	25	172	20.7	1930	221	8.3	7.9	2.1	97	0.25	0.46	26.8
F-3	BOTTOM	550	550	23.3	4180	275	12.4	8.6	7	129	0.39	1.80	59.8
	Mini	40	40	1.6	800	152	0.8	7.3	0	63	0.03	0.04	10.8
	Mean	198	198	16.9	1870	226	5.6	7.7	4.1	100	0.14	0.62	25.6

Table 3. Maximum, minimum, and mean values for the zooplankton species (no./l), total zooplankton (no./l) and zooplankton biomass (mg/l) occurring in the three turbid (T) ponds from March through October, 1974.

Zooplankton Species	Pond T-1			Pond T-2			Pond T-3		
	Max	Mini	Mean	Max	Mini	Mean	Max	Mini	Mean
<u>Filinia longiseta</u>	619.3	0.0	68.2	783.8	0.0	63.2	93.7	0.0	27.8
<u>Asplanchna</u> sp.	38.1	0.0	4.1	419.2	0.0	59.3	11.9	0.0	3.0
<u>Keratella cochlearis</u>	1296.4	0.9	150.2	571.0	0.0	79.2	87.1	0.0	25.4
<u>Cyclops</u> sp.	61.6	0.9	30.4	510.4	0.0	132.2	62.2	5.0	24.7
<u>Diaptomus</u> sp.	33.4	7.1	18.4	391.9	0.0	80.2	75.0	4.0	23.7
Copepod nauplii	97.5	15.2	53.0	1220.2	30.3	359.8	397.1	26.4	144.9
<u>Daphnia</u> sp.	16.1	0.0	3.9	117.8	0.0	22.1	40.4	0.0	12.3
<u>Ceriodaphnia lacustris</u>	27.1	0.0	5.9	1.9	0.0	0.1	186.6	0.0	52.0
<u>Bosmina longirostris</u>	242.4	0.9	54.9	5.7	0.0	0.9	147.6	0.0	18.6
<u>Diaphanosoma brachyurum</u>	10.8	0.0	2.5	0.0	0.0	0.0	36.1	0.0	6.8
<u>Macrothrix laticornis</u>	0.0	0.0	0.0	64.4	0.0	6.1	0.0	0.0	0.0
Total Zooplankton	1983.0	76.6	580.0	1561.6	62.1	803.1	808.6	73.8	339.2
Zooplankton Biomass	0.4	0.1	0.2	1.9	0.5	1.2	0.9	0.1	0.4

Table 4. Maximum, minimum, and mean values for the zooplankton species (no./l), total zooplankton species (no./l), and zooplankton biomass (mg/l) occurring in the three clear (C) ponds.

Zooplankton Species	Pond C-1			Pond C-2			Pond C-3		
	Max	Mini	Mean	Max	Mini	Mean	Max	Mini	Mean
<u>Filinia longiseta</u>	1.4	0.0	0.3	0.0	0.0	0.0	67.4	0.0	7.4
<u>Asplanchna</u> sp.	17.9	0.0	3.2	4.8	0.0	0.3	7.0	0.0	0.5
<u>Keratella cochlearis</u>	853.8	1.4	113.0	124.7	0.0	18.3	195.5	0.0	29.4
<u>Cyclops</u> sp.	74.2	0.0	24.7	71.5	0.0	18.8	16.6	0.0	5.7
<u>Diaptomus</u> sp.	0.0	0.0	0.0	0.0	0.0	0.0	32.3	1.0	10.2
Copepod nauplii	171.2	10.6	59.0	284.8	37.6	125.8	92.9	11.7	42.0
<u>Daphnia</u> sp.	0.0	0.0	0.1	190.3	0.0	36.6	112.7	1.0	27.8
<u>Ceriodaphnia lacustris</u>	0.0	0.0	0.0	0.0	0.0	0.9	4.0	0.0	0.6
<u>Bosmina longirestris</u>	793.9	0.0	172.5	277.6	0.0	33.9	56.6	0.0	12.3
<u>Diaphanosoma brachyurum</u>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
<u>Macrothrix laticornis</u>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Zooplankton	951.5	49.6	372.8	602.4	50.9	238.2	298.1	55.7	135.4
Zooplankton Biomass	0.3	0.0	0.1	0.6	0.0	0.2	0.7	0.1	0.2

LIMNOLOGICAL INVESTIGATIONS OF SOME TURBID
AND CLEAR FLINT HILLS FARM PONDS

by

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ABSTRACT

The purposes of this study were to monitor and illustrate the levels of the selected physical, chemical, and biological characteristics of the three clear and three turbid Kansas Flint Hills farm ponds, note any of the important differences between the two pond types, and describe the relationships between the variables being measured and their significance. Each pond was investigated by sampling every two weeks from March, 1974 until October, 1974.

The turbid ponds had significantly greater average turbidity and lower water level below the outlet than the clear ponds, while temperatures did not differ between pond types. Particulate organic matter densities averaged nearly always higher in the turbid ponds, although neither of the two pond types had levels that were significantly different. Of the chemical characteristics, total alkalinity and hydrogen-ion concentrations were significantly higher in the clear ponds, while nitrate-nitrogen values were significantly greater in the turbid ponds. Free carbon dioxide and dissolved oxygen had concentrations that were not significantly different between the two pond types. Specific conductivities and orthophosphate levels were not significantly different in either the clear or the turbid ponds, but their averages showed that the conductivities were higher in the clear ponds, and the orthophosphate concentrations were greater in the turbid ponds.

Biological characteristics were analyzed, and it was found that chlorophyll-a concentrations averaged much higher in the turbid ponds, but the ponds were not significantly different. All zooplankton

genera occurring in the ponds were identified, and the densities of Filinia longiseta, Diaptomus sp., total zooplankton number, and zooplankton biomass were significantly greater in the turbid ponds. Keratella cochlearis, Asplanchna sp., Daphnia sp., Bosmina longirostris, Ceriodaphnia lacustris, Cyclops sp., and copepod nauplii were not statistically different in abundance in either one of the two types of ponds. Ceriodaphnia lacustris and Cyclops sp. had greater average population sizes in the turbid ponds, although there was no significant difference between pond types. Diaphanosoma brachyurum occurred only in two of the three turbid ponds, and Macrothrix laticornis occurred in only one of the turbid ponds.