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PHYSICAL AND CHEMICAL LIMNOLOGY OF COTTONWOOD POND AND SPRING POND (SEPT. 1969--DEC. 1970)

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ABSTRACT

For the period September 1969 to December 1970, the following physical and chemical parameters were studied monthly in Cottonwood Pond and Spring Pond on the Pawnee Site: temperature, dissolved oxygen, hydrogen ion concentration, turbidity, total residue, conductance, hardness (total Ca, Mg), sodium, potassium, alkalinity (P and T), chloride, and sulfate. Several other variables were studied on an irregular basis: iron, phosphate, nitrate, and ammonia. In addition, a complete morphometric consideration of each pond was made.

INTRODUCTION

This report is a presentation and discussion of the physical and chemical data of selected representative lentic sites on the Pawnee Site from September 1969 to December 1970. At its outset, this study was to include physico-chemical investigations of temporary habitats such as Lynn Lake, Lake George, and certain swale ponds. However, such investigations were not possible, since precipitation patterns were such as to never fill these temporary ponds during the study period. On the other hand, Spring Pond (semi-permanent) and Cottonwood Pond (permanent) contained water during the entire study period, were intensively investigated on at least a monthly basis (semi-monthly in many instances), and provided all the data contained herein.

MATERIALS AND TECHNIQUES

Specific methods are outlined in an earlier report (Herrmann, LaVelle, and Seilheimer 1970). In addition, temperature gradients were made using a Yellow Springs Instrument model 43 telethermometer, and conductance measurements were made on membrane filtered samples using a Beckman RB3-334I solu bridge conductivity unit. Top to bottom composite water samples were taken at least monthly at station Y in Spring Pond (Fig. 1) and station C in Cottonwood Pond (Fig. 2). Morphometry determinations were made using the survey by transverse measurements method of Welch (1948) and were verified with aerial photographs.

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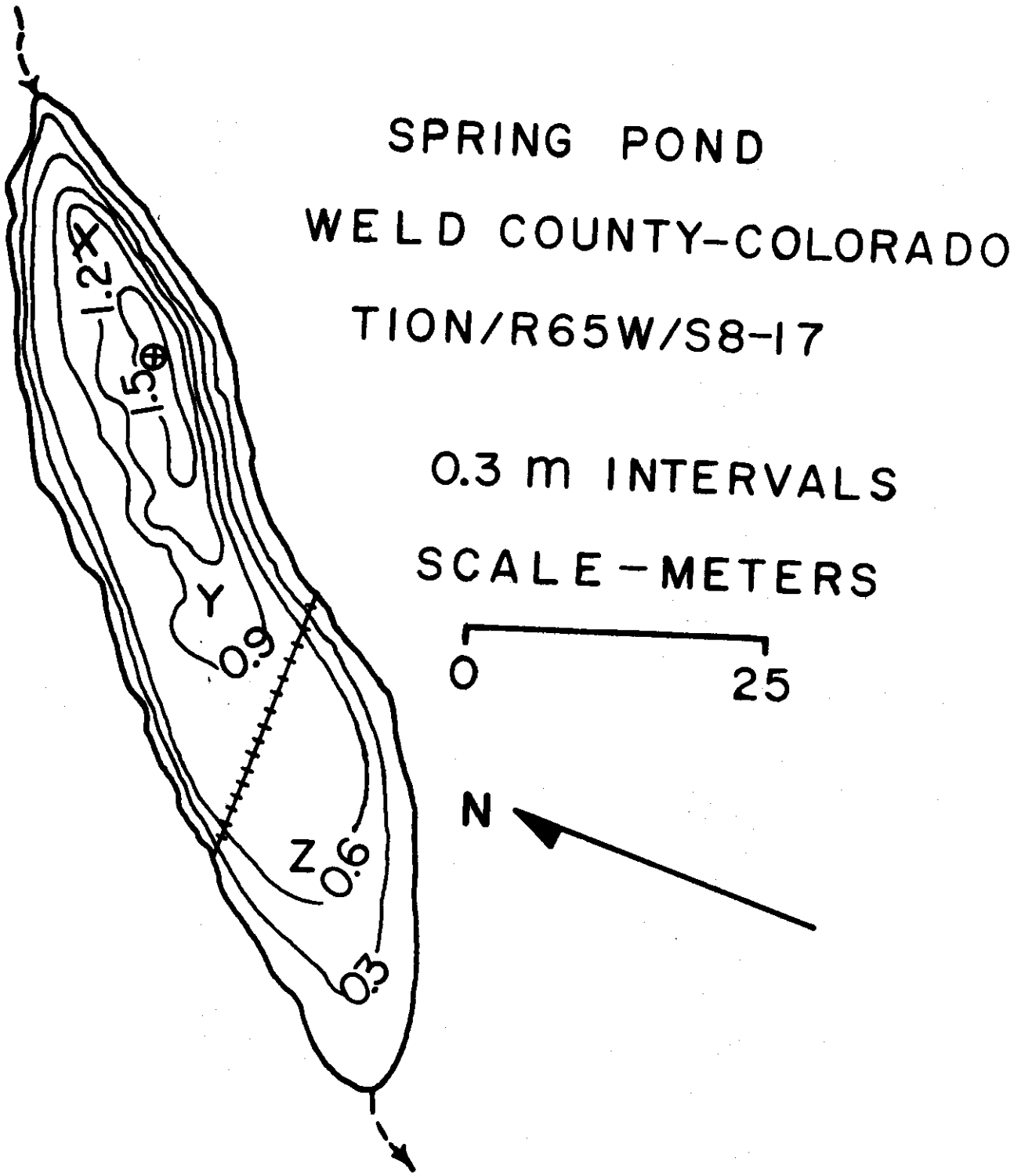

Fig. 1. Morphometric map of Spring Pond (27 June 1970). Letters X, Y, and Z represent collection sites; the crossed circle locates point of maximum depth; and cross-hatched line depicts barb wire fence.

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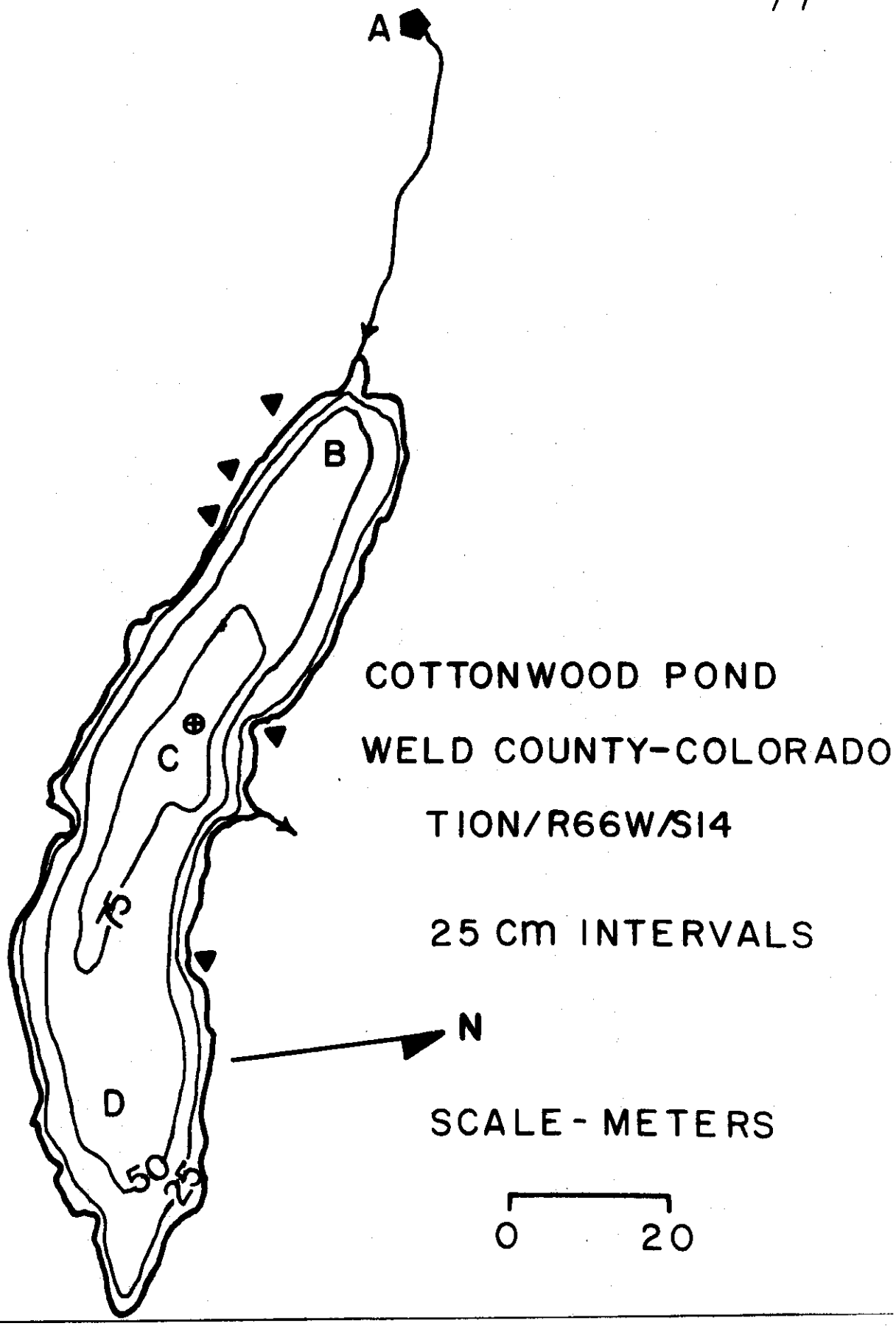

Fig. 2. Morphometric map of Cottonwood Pond (23 January 1970). Solid triangles represent cottonwood trees; crossed circle marks point of maximum depth; solid pentagon locates spring source; and letters A, B, C, and D mark collection sites.

RESULTS

Morphometry--Spring Pond

The bathymetric map shown in Fig. 1 was compiled from data collected 27 June 1969, when Spring Pond was at maximum water level and was overflowing into the intermittent stream of which it is a part. During periods of scant or no precipitation, the water level may fluctuate greatly. For example, during the intensive study period, a drop in water level of 65 cm was observed between 26 April 1970 and 11 September 1970. Preliminary morphometric data (LaVelle et al. 1969) should be supplanted by that contained in Tables 1 and 2. Note that more than half the surface area of Spring Pond has a depth greater than 60 cm during periods of maximum water level; that more than 70% of the total volume is contained within the first two bathymetric contours, 0.3 m and 0.6 m, respectively; and that the mean depth ($\bar{z}$) is nearly 1/3 the maximum depth (z_m).

Morphometry--Cottonwood Pond

A morphometric map of Cottonwood Pond (Fig. 2) was drawn from data collected 23 January 1970 when the water level was at its most commonly observed position. During periods of heavy runoff (April to August), the water level may be elevated 4 to 7 cm. Such periods are usually few in number and short in duration, with the pond returning to its most frequent monthly level. Cottonwood Pond does not fluctuate violently, relative to deficient precipitation and periods of excessive evaporation; this is, in part, due to a permanent spring source approximately 45 m upslope from the inlet. This spring emits a constant flow of water directly into Cottonwood Pond, even during drought periods. The preliminary morphometric data

Table 1. Areas and volumes by depth intervals for Spring Pond (27 June 1969).

z (m)	A_z (m^2)	V (m^3)	Percent of Total Volume
0.00	1328	353	39.7
0.30	1032	273	30.7
0.60	794	162	18.2
0.90	320	71	7.9
1.20	160	28	3.1
1.50	39	3	0.4
1.65	8		
		V (total) = 890 m^3	

Table 2. Morphometric parameters derived from Fig. 1 and Table 1 for Spring Pond. Notation and definitions follow Hutchinson (1957).

Surface area (A_o) of pond	1328 m^2 → 1
Maximum depth ($Z\underline{m}$)	1.65 m
Mean depth ($\bar{z}$)	0.67 m
Length (l)	91.75 m
Mean breadth ($\bar{b}$)	14.47 m
Length of shoreline (L_o)	192.50 m
Shore development (D_L)	1.49
Volume development (D_V)	1.22

of LaVelle, et al. (1969) should be supplanted by the more definitive information contained in Tables 3 and 4. In contrast to Spring Pond, this lentic habitat has nearly twice the surface area, one and one half the volume, and one and one half the length; but Cottonwood Pond has a lesser maximum and mean depth.

Temperature

Temperature curves in Fig. 3 are representative of both Spring (station Y) and Cottonwood (station C). Ice covers both ponds about equally from the beginning of December to the end of March. Departures from such an ice cover period can be expected and are a result of unseasonally warm days at either end of the period. Relatively uniform temperatures from the surface to the sediment-water interface are the rule for these two relatively shallow wind-whipped ponds. Strong daily winds are common on the Pawnee shortgrass prairie, and they effectively mix the water of both basins such that stagnant and stable conditions rarely exist. On only two occasions was there a sharp temperature gradient between the surface and mid-depth (30 cm)--26 March and 9 July.

Subsurface Dissolved Oxygen

For both bonds, subsurface dissolved oxygen conditions were quite variable, depending on local weather conditions and the time of day. During periods of ice cover (December to March), large fluctuations were observed.

With conditions such as thin ice (2 to 4 cm), no snow cover, sunny skies, and mid-day solar radiation, subsurface dissolved oxygen levels can be extremely high. On 8 December 1970 such conditions existed and the following subsurface concentrations were recorded:

Table 3. Areas and volumes by depth intervals for Cottonwood Pond (23 January 1970).

z (m)	A_z (m^2)	V (m^3)	Percent of Total Volume
0.00	2516	570	46.2
0.25	2050	433	35.1
0.50	1429	201	16.3
0.75	313	29	2.4
0.98	12		
		V (total) = 1233 m^3	

Table 4. Morphometric parameters derived from Fig. 2 and Table 3 for Cottonwood Pond. Notation and definitions follow Hutchinson (1957).

Surface area (A_o) of pond	2516 m^2 → 1
Maximum depth (Z_m)	0.98 m
Mean depth ($\bar{z}$)	0.49 m
Length (1)	131.00 m
Mean breadth ($\bar{b}$)	19.21 m
Length of shoreline (L_o)	318.30 m
Shore development (D_L)	1.80
Volume development (D_V)	1.50

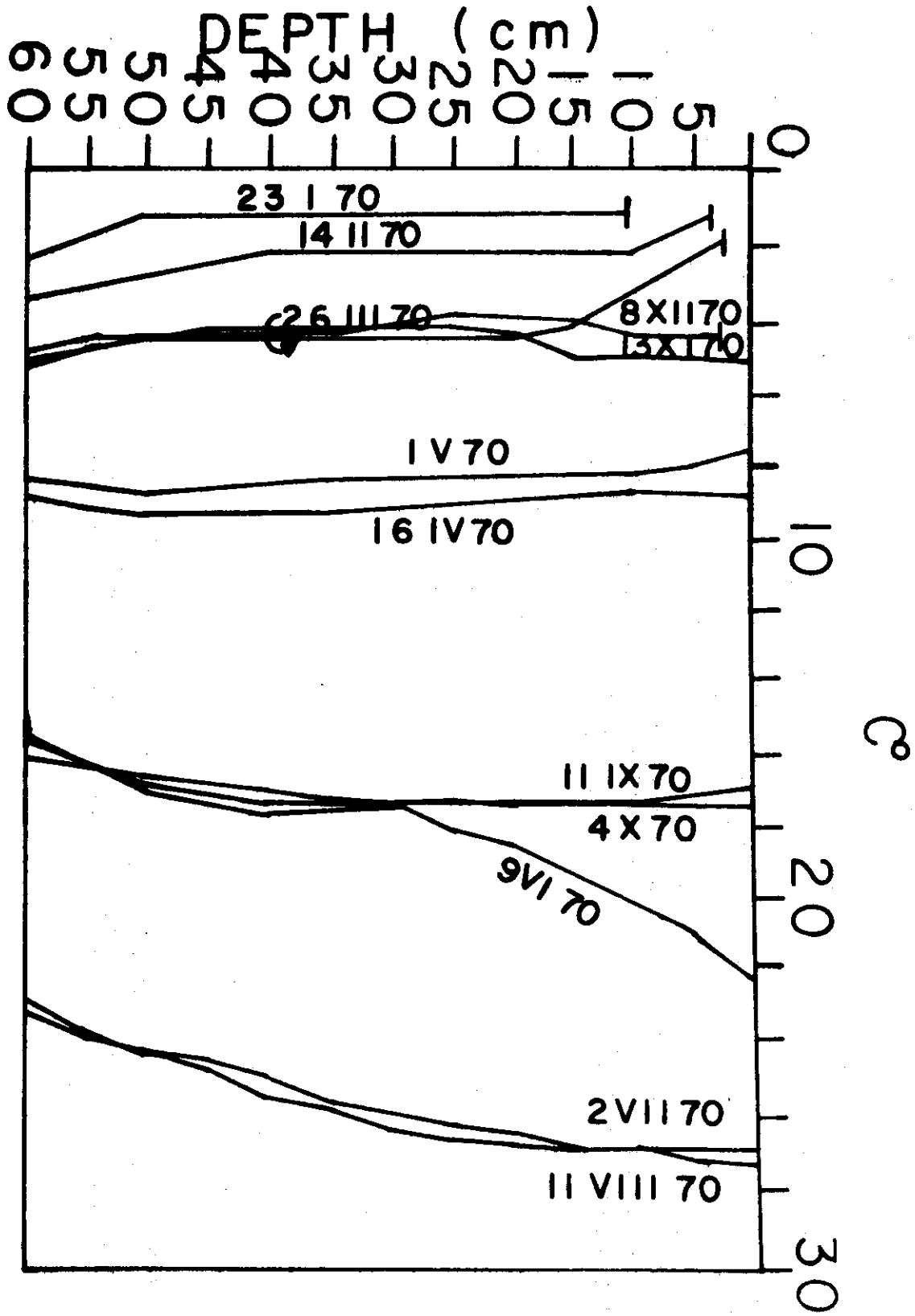

Fig. 3. Temperature gradients of Spring Pond and Cottonwood Pond for 1970.

Cottonwood Pond	21.0 ppm
Spring Pond	16.6 ppm

Under more severe winter conditions (thicker ice, snow cover, and overcast skies), anaerobic conditions do exist in both ponds.

During open water months (April to November), subsurface dissolved oxygen levels were quite variable, but never were below 3.0 ppm. The mixing action of the wind during the open season probably maintains relatively uniform dissolved oxygen levels at most depths in both Cottonwood and Spring Ponds.

Hydrogen Ion Concentration

Mode pH values for both ponds are given below (range in parentheses).

Spring Pond	9.4 (8.5 - 10.0)
Cottonwood Pond	8.6 (7.4 - 10.0)

It is interesting to note the greater range for the more stable of the two. In Cottonwood Pond, pH values tend to increase during the period from June to October and decrease from November to May. Mild irregularities in this trend were recorded and are due to unseasonal climatic changes and other factors. In Spring Pond, seasonal pH trends were not to be found. Water levels in Spring Pond may be very different for a given month from year to year; hence, pH values are most often reflections of solute dilution or concentration.

Turbidity

Jackson turbidity units were the standard for monthly turbidimetric determination in each pond (Fig. 4). Note that Spring Pond turbidity values were always greater than those of Cottonwood Pond and that values for both

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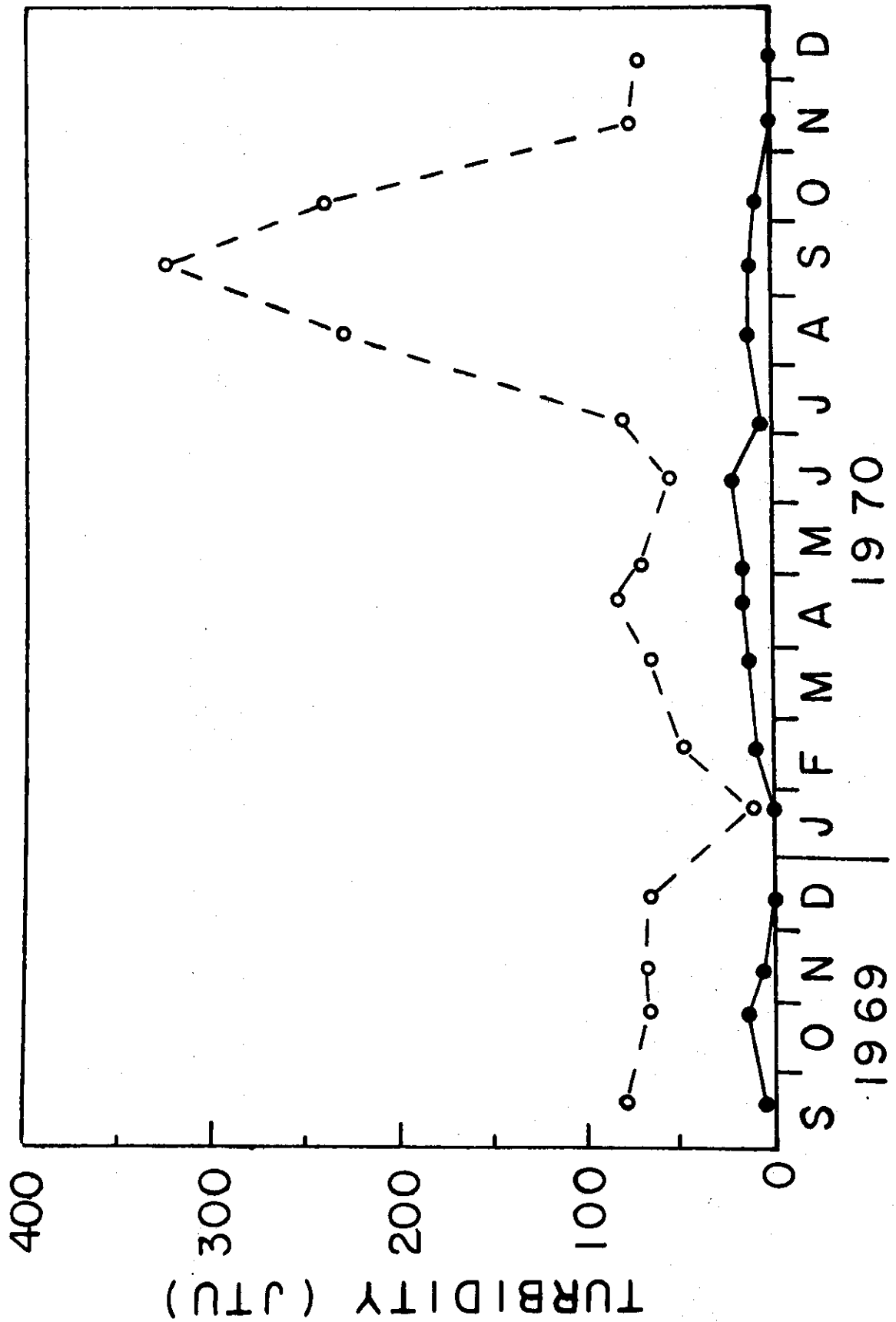

Fig. 4. Turbidity for Spring Pond (open circles) and Cottonwood Pond (solid circles).

ponds were greatly decreased during periods of ice cover. Water level stability and emergent vegetation make Cottonwood Pond a much less turbid habitat.

Total Residue (Non-filtered Residue)

In March, April, and May total residue values are at their maximum for Cottonwood Pond and in September, October, November, and December for Spring Pond (Fig. 5). Note the tremendous jump in total residue for Spring Pond during the fall of 1970 versus that of 1969. The percent organic content for Spring Pond and Cottonwood Pond was 11.91% and 13.95%, respectively.

Conductance

Monthly conductivity values for each pond show some interesting total salt content changes (Fig. 6). During the ice-out period and for several months thereafter (March to May), the total salt content of Spring Pond decreases, while that of Cottonwood Pond increases. Notice the sharp increase during the summer and fall of 1970 in Spring Pond.

Hardness (Total, Calcium, Magnesium)

Total hardness, calcium hardness, and magnesium hardness values for each pond are shown in Fig. 7, 8, and 9, respectively. Total hardness was usually greater in Cottonwood Pond except during August, September, and October of 1970. Calcium hardness levels quite closely follow the total hardness values. Magnesium hardness was generally higher in Cottonwood Pond; however, in the last five months of 1970, Spring Pond was in excess.

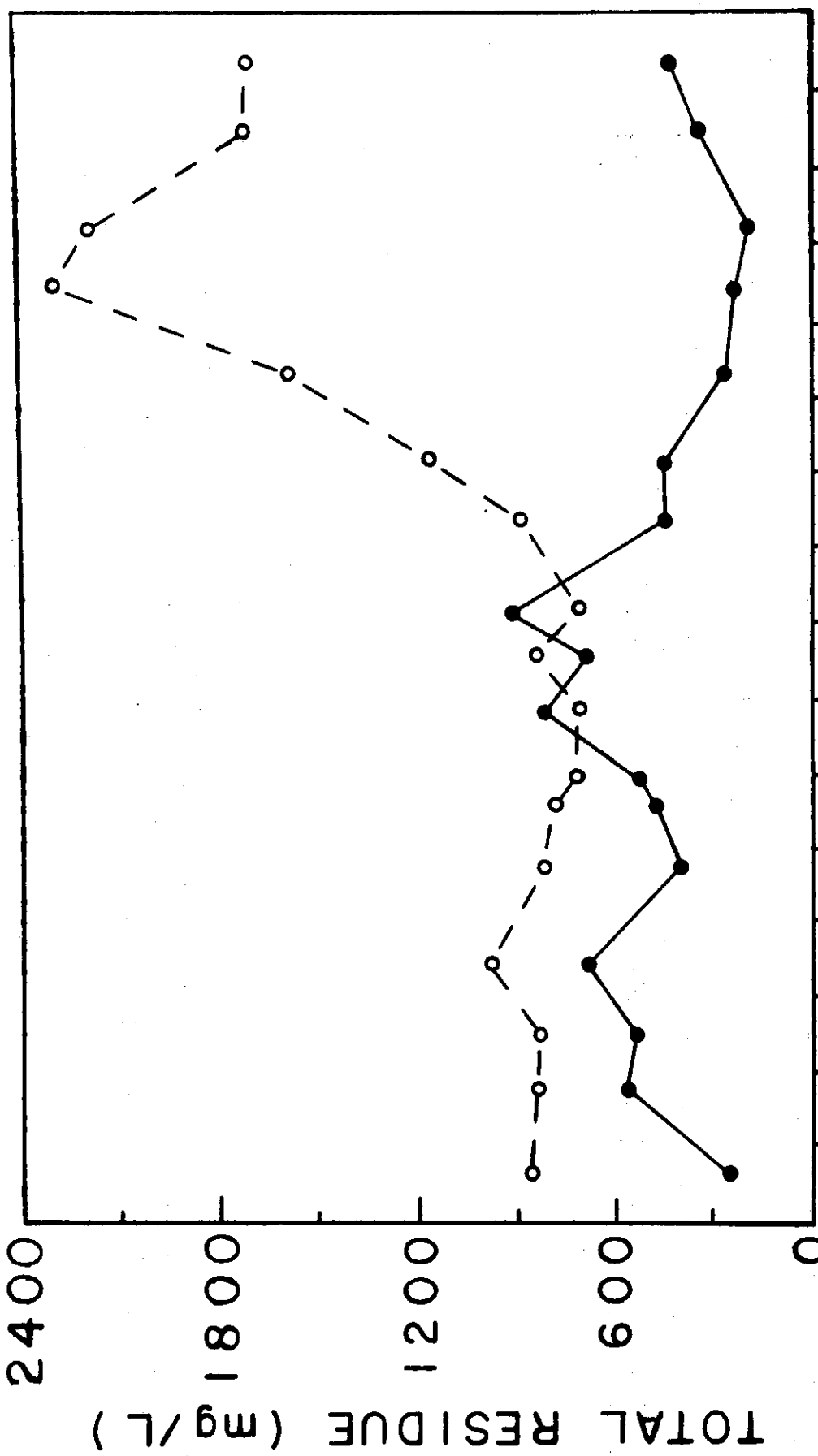

Fig. 5. Total residue for Spring Pond (open circles) and Cottonwood Pond (solid circles).

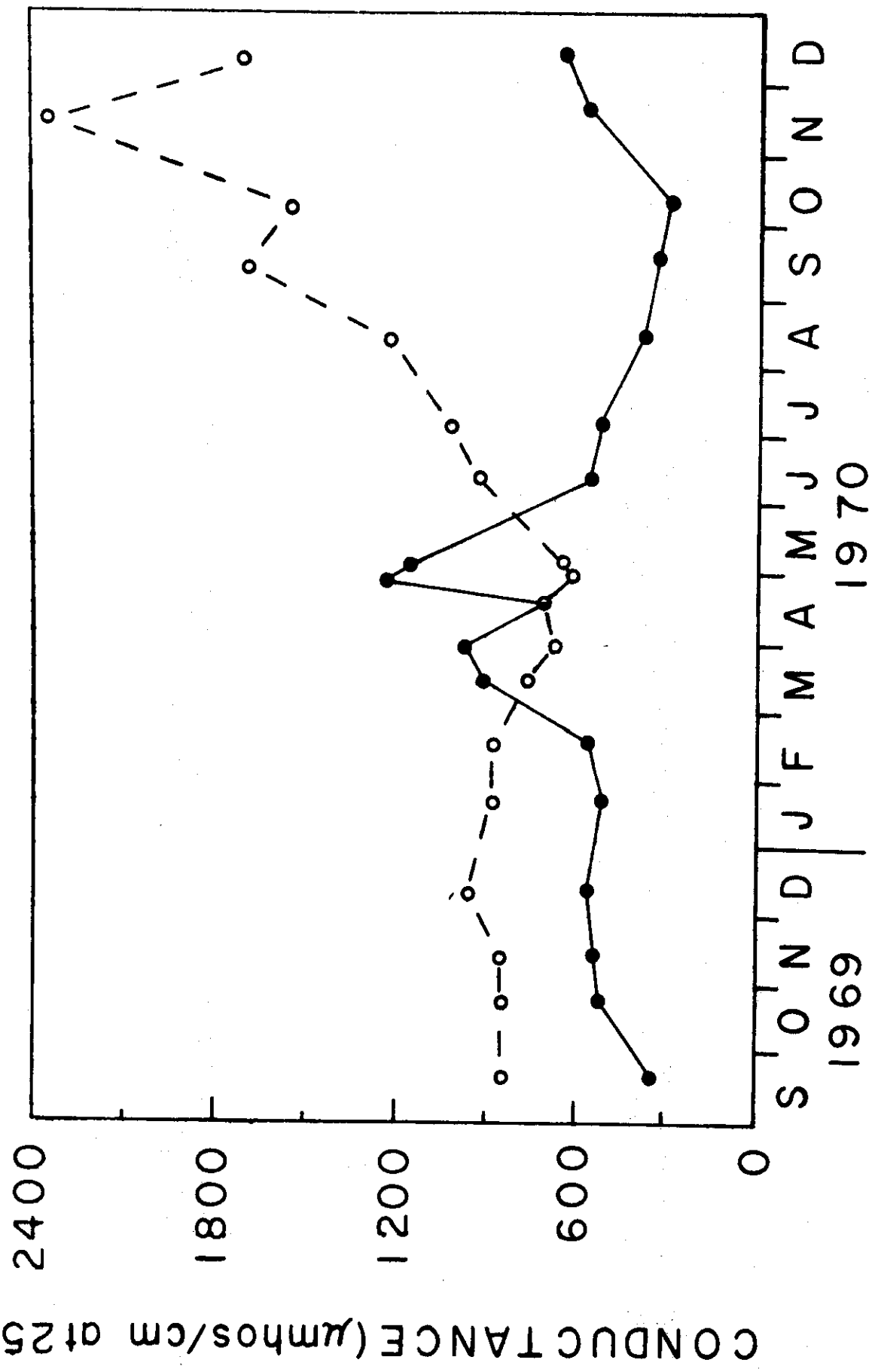

Fig. 6. Conductance for Spring Pond (open circles) and Cottonwood Pond (solid circles).

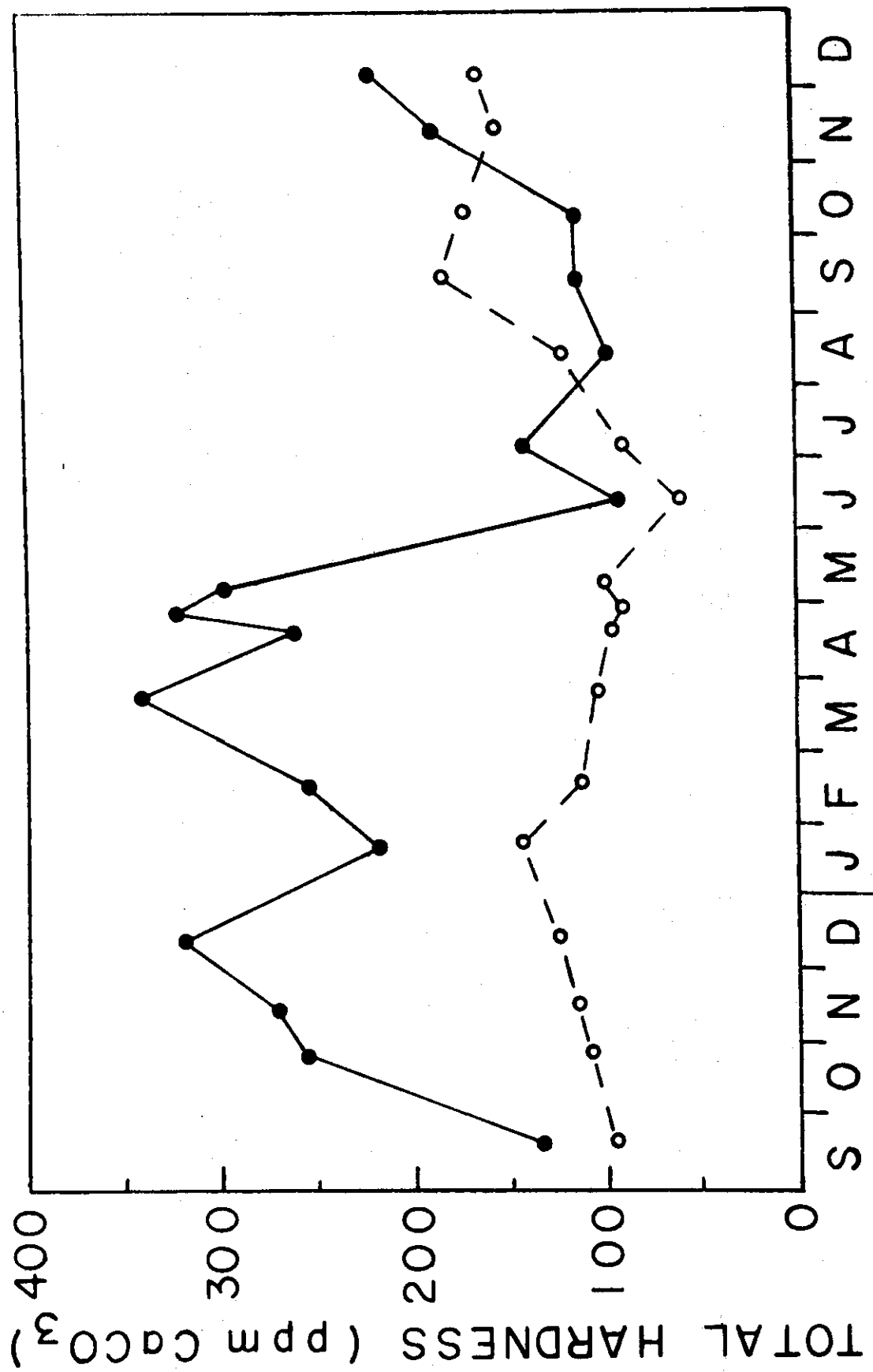

Fig. 7. Total hardness for Spring Pond (open circles) and Cottonwood Pond (solid circles).

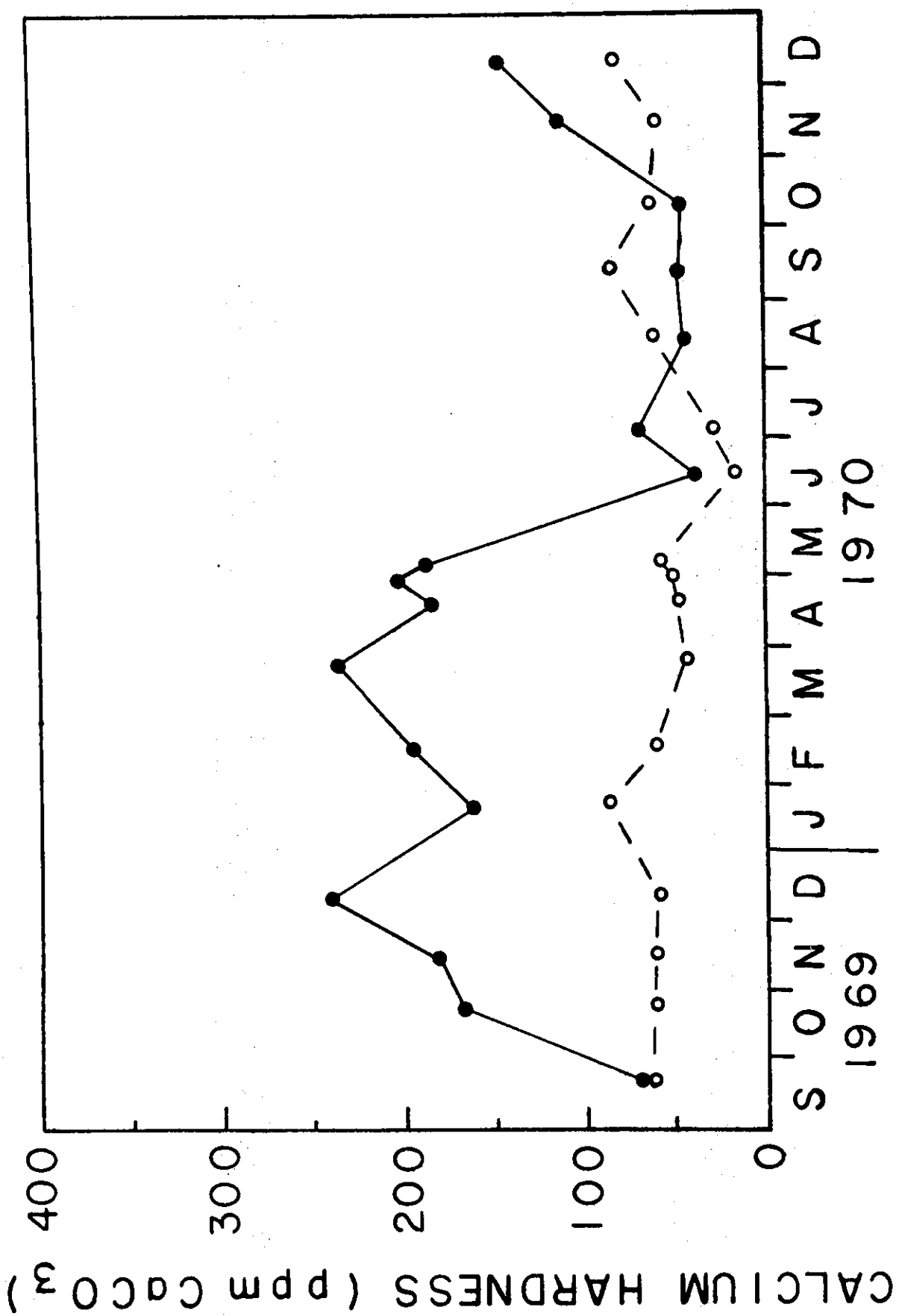

Fig. 8. Calcium hardness for Spring Pond (open circles) and Cottonwood Pond (closed circles).

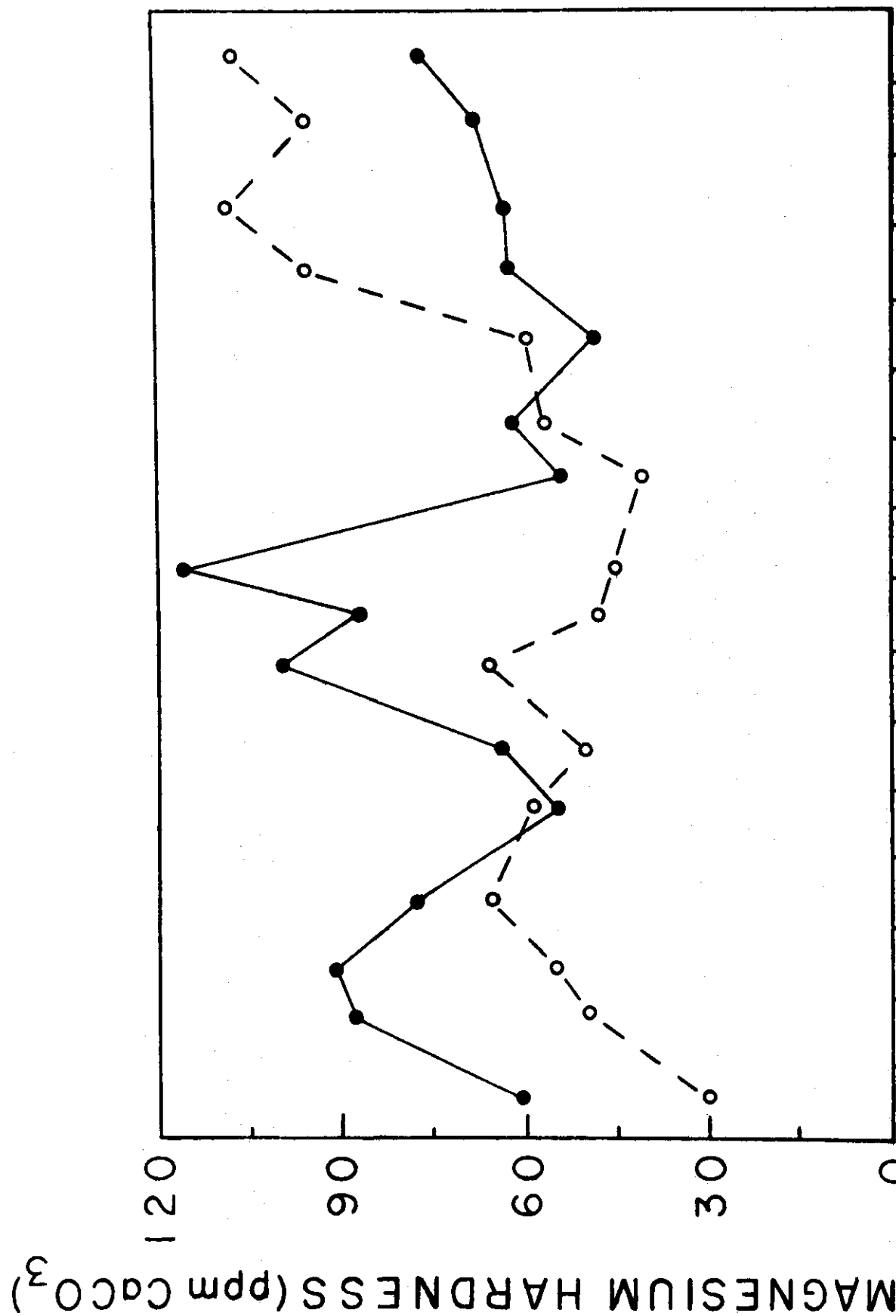

Fig. 9. Magnesium hardness for Spring Pond (open circles) and Cottonwood Pond (closed circles).

Sodium

Sodium concentrations were generally much greater in Spring Pond, except during April and May of 1970, when Cottonwood Pond values were in excess (Fig. 10). A vernal decrease was obvious in Spring Pond, while a vernal increase was obvious in Cottonwood Pond.

Potassium

Potassium concentrations were very stable in Cottonwood Pond and Spring Pond, except for an approximate doubling in the latter during the period from August to December 1970 (Fig. 11).

Iron

Ferrozine iron determinations reveal low levels of ferrous iron in Spring and Cottonwood Ponds. In Cottonwood Pond, concentrations never exceeded 0.01 ppm; while in Spring Pond, the range was 0.02 to 0.05 ppm.

Alkalinity

Total alkalinity values were always greater in Spring Pond (Fig. 12). Great fluctuations were the rule in Spring Pond, but not in Cottonwood Pond. Phenolphthalein alkalinity values greater than zero were recorded for Spring Pond on all but two dates: 23 January 1970 and 11 August 1970. On the former date, Spring Pond was covered with 11 cm ice; and on the latter date, sampling was done at 0835 MST. On the other hand, P-alkalinity values (>0) for Cottonwood Pond were recorded only during the period from June to October 1970.

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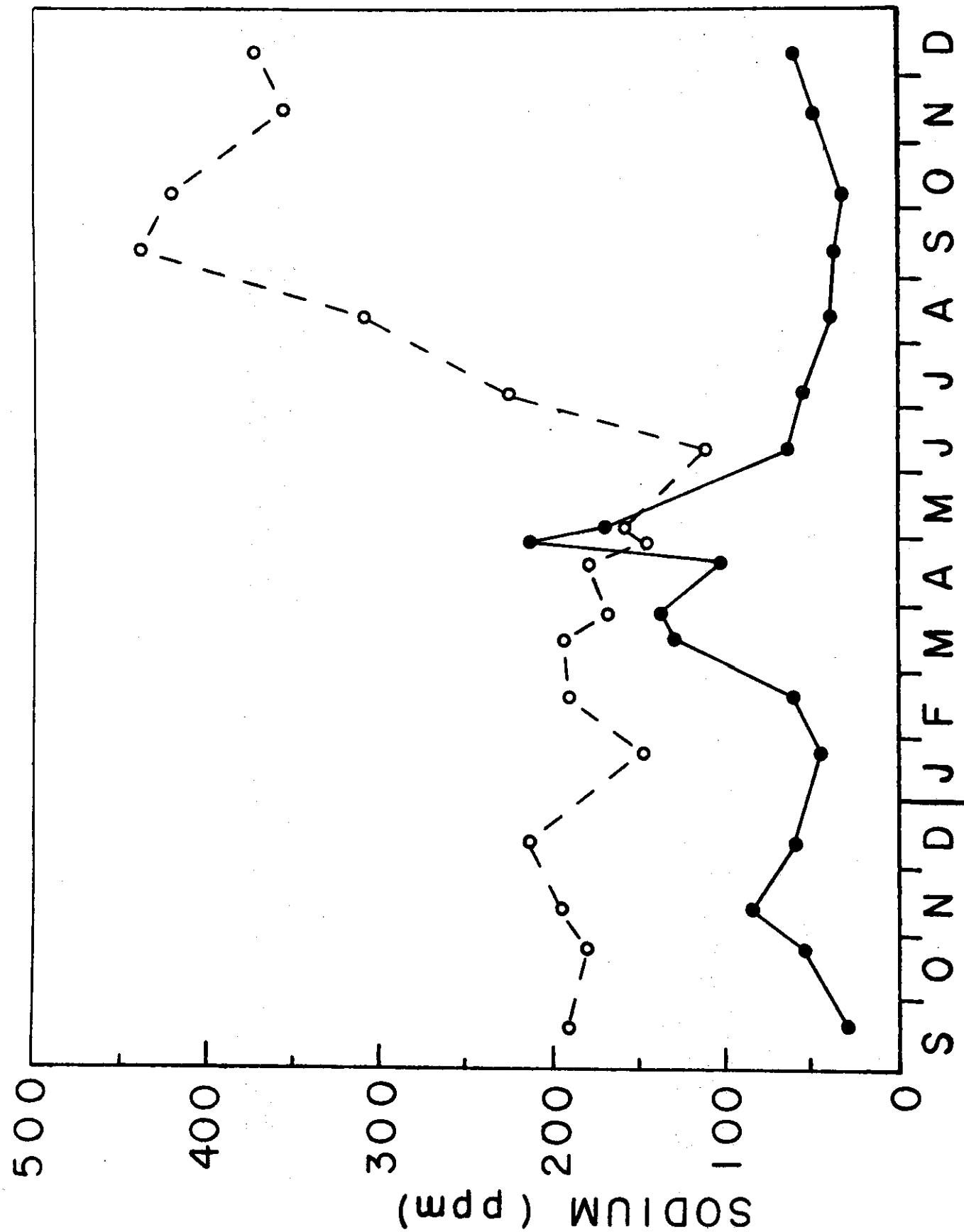

Fig. 10. Sodium concentration for Spring Pond (open circles) and Cottonwood Pond (closed

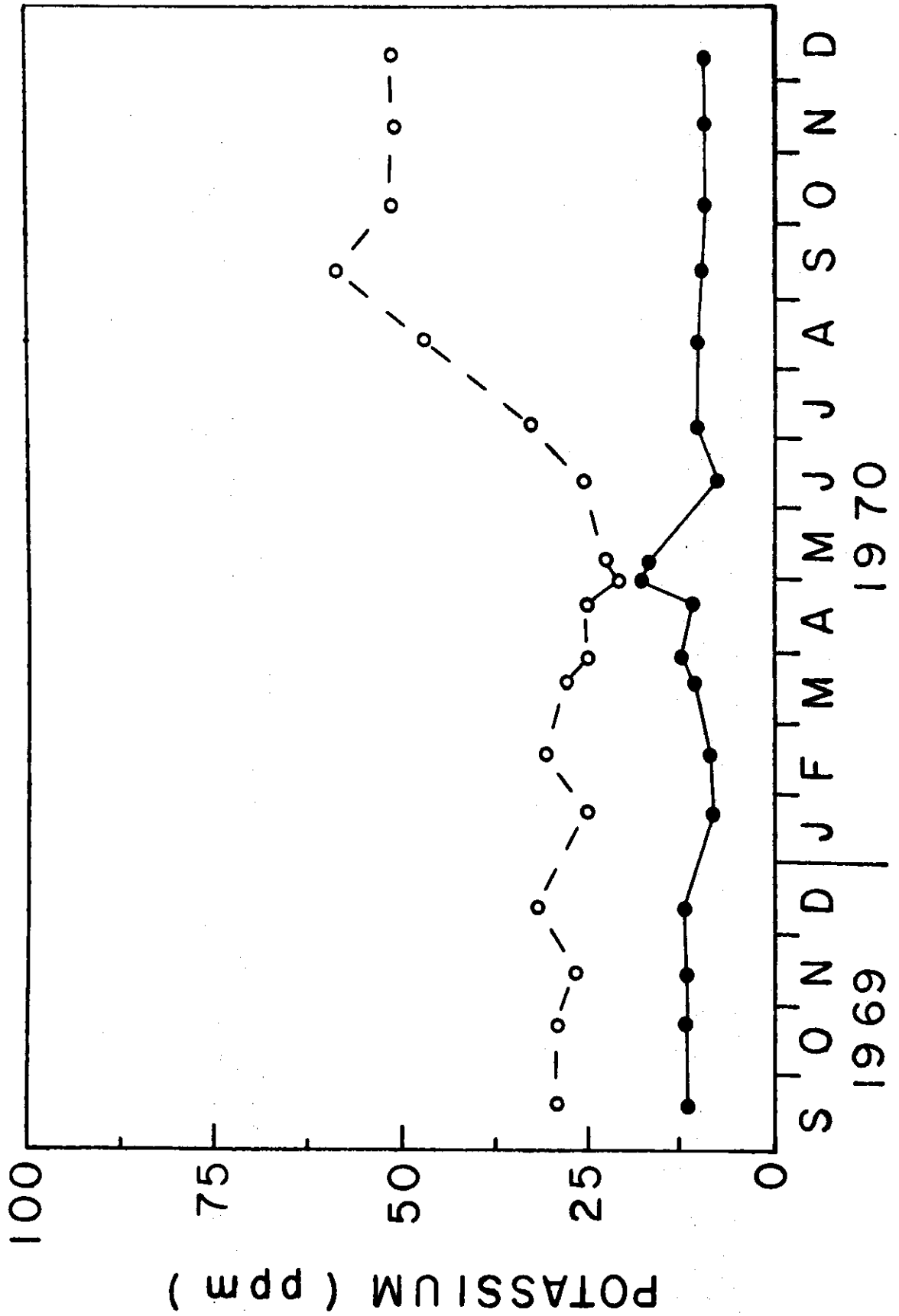

Fig. 11. Potassium concentration for Spring Pond (open circles) and Cottonwood Pond (closed circles).

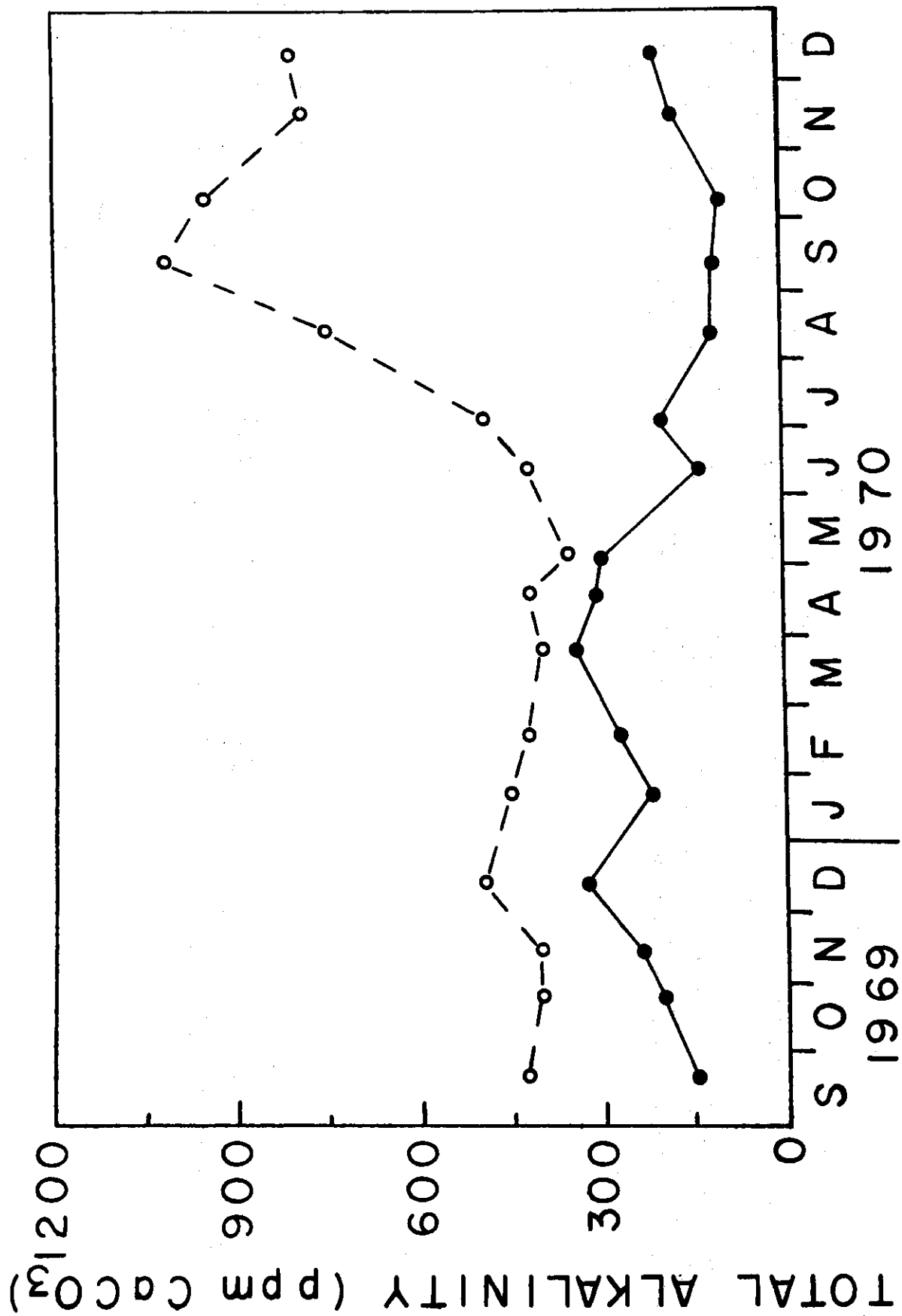

Fig. 12. Total alkalinity for Spring Pond (open circles) and Cottonwood Pond (closed circles).

Chloride

Monthly chloride levels are shown in Fig. 13. Except during the spring of 1970, Spring Pond generally had greater chloride concentrations.

Sulfate

Sulfate concentrations tended to increase continually in Spring Pond, while fluctuating greatly in Cottonwood Pond (Fig. 14).

Phosphate

Orthophosphate levels were generally twice as great in Spring Pond. Mean orthophosphate levels for January, April, July, and October (1970) samples were as follows. Mean polyphosphate concentrations for the same sets of samples are given in parentheses.

Cottonwood Pond	0.02 ppm (0.06 ppm)
Spring Pond	0.05 ppm (0.18 ppm)

Nitrogen

Nitrate concentrations for both ponds were relatively low. The range in nitrate for each pond was as follows:

Cottonwood Pond	0.06 - 0.07 ppm
Spring Pond	0.01 - 0.13 ppm

Ammonia nitrogen was not determined except on 8 December 1970. On this date, ammonia levels were undetectable in either pond by the (Hach) Nesslerization procedure. During periods of winter and, possibly, summer stagnation, relatively high ammonia levels in Spring Pond are to be expected.

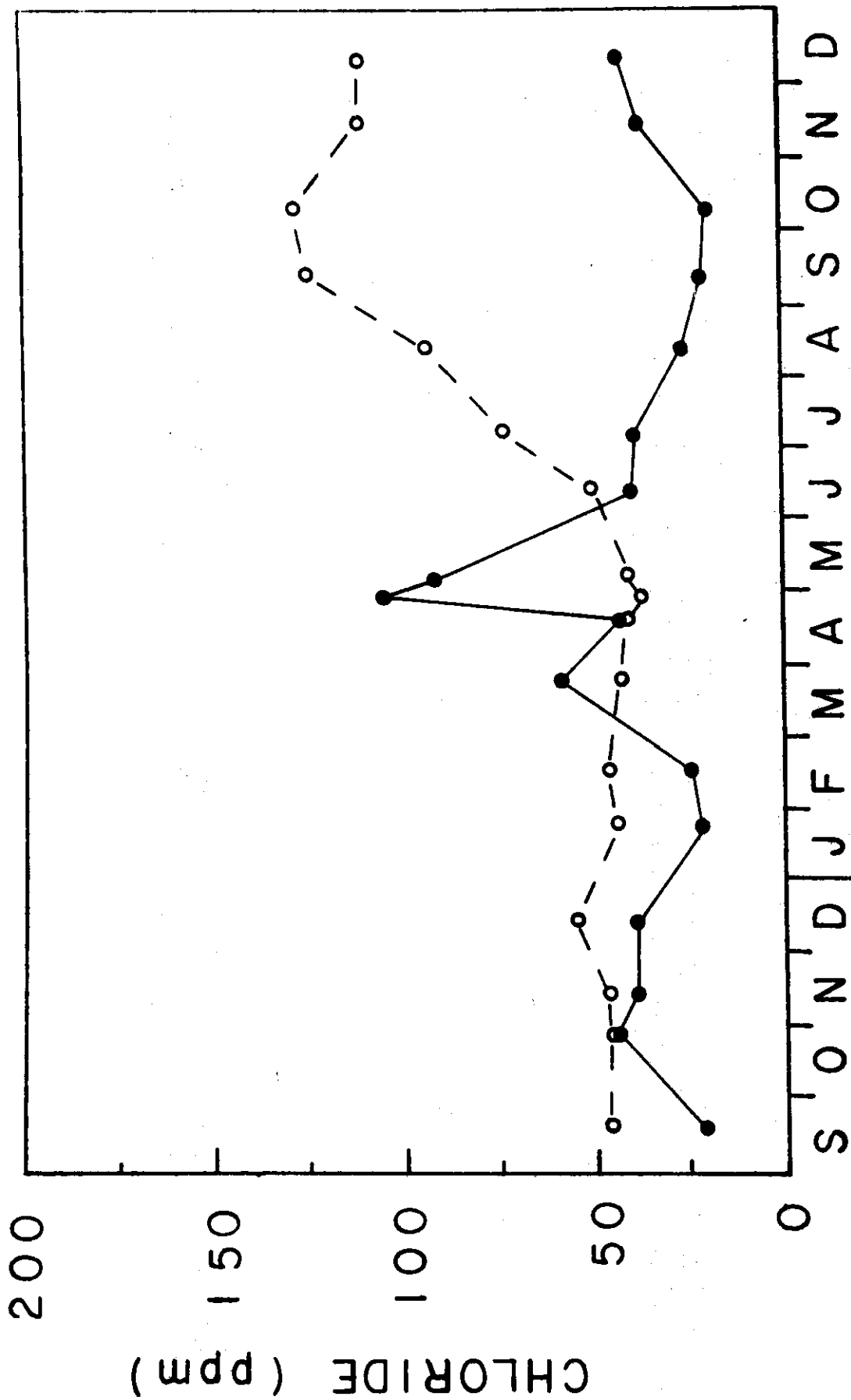

Fig. 13. Chloride concentration for Spring Pond (open circles) and Cottonwood Pond (closed circles).

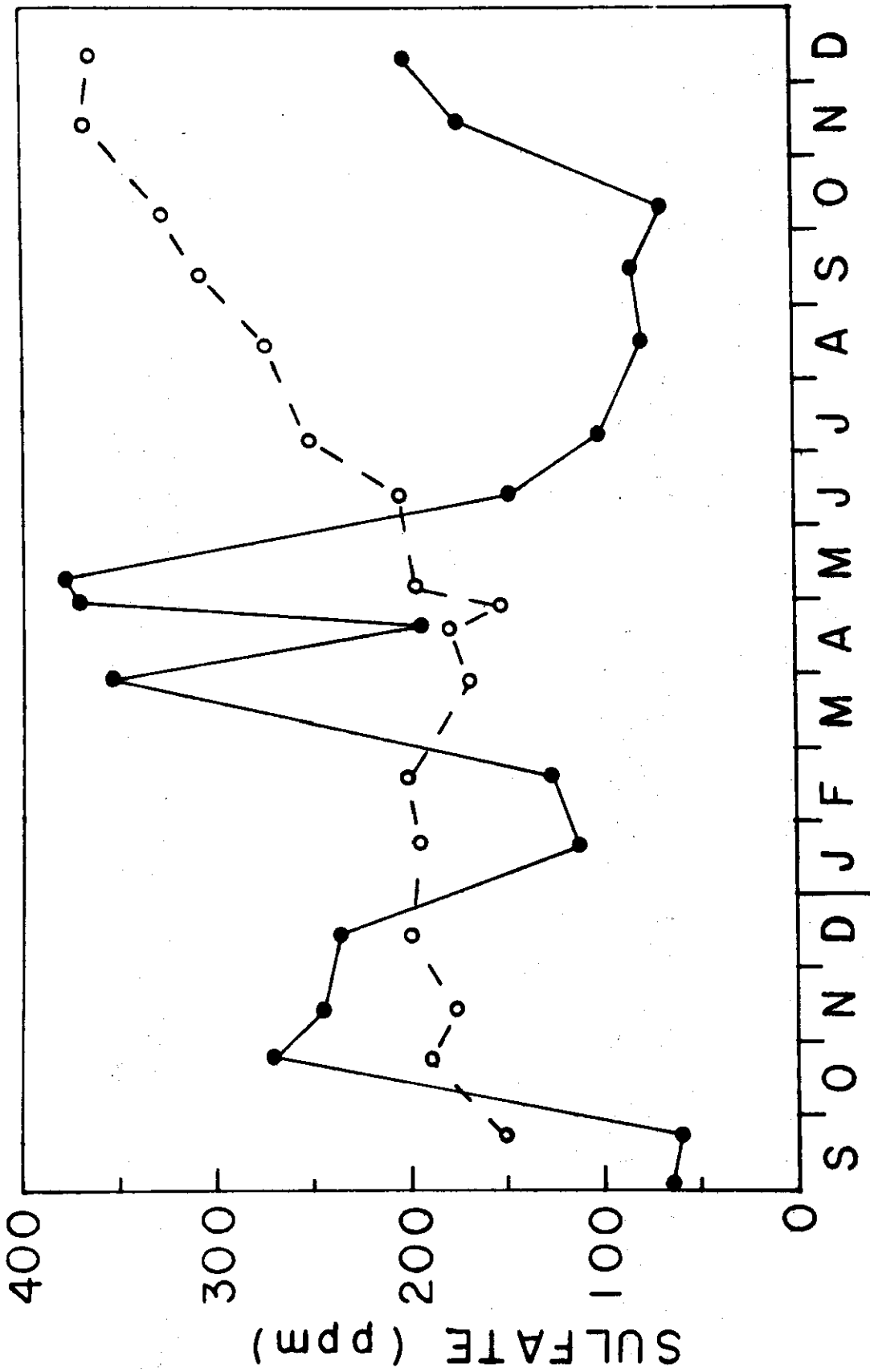

Fig. 14. Sulfate concentration for Spring Pond (open circles) and Cottonwood Pond (closed circles).

DISCUSSION

Three primary driving forces on the Pawnee Site greatly influence the physico-chemical parameters of the lentic habitats studied: wind, precipitation, and solar radiation. Forty-four years ago, Jewell (1927) had already emphasized the effect of wind on the turbidity of prairie ponds. Besides affecting turbidity, the wind also hastens evaporation rates, increases wave action and, concomitantly, dissolved oxygen concentrations, and causes allochthonous organic material to be deposited and concentrated in Pawnee lentic sites.

Spring Pond and Cottonwood Pond are both alkali plains lakes according to Pennak (1958) and Herrmann (1970); but each pond is distinctive as its mean concentration of each ion. quite possibly, a more detailed chemical classification of Colorado plains lakes is necessary. Both ponds studied are quite different from the temporary Canadian ponds studied by Mozley (1932) and Hartland-Rowe (1966), and are distinct from Pawnee temporary ponds as well.

Physical and chemical parameters of aquatic ecosystems have profound effects on primary productivity. Butler (1965) found that various environmental interactions had a significant effect on gross summer productivity. Some of these significant interactions were: light intensity and total dissolved inorganic solids, light intensity and temperature, temperature and dissolved solids, and turbidity and dissolved solids. Further study should reveal similar interactions for Spring Pond and Cottonwood Pond.

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