

Technical Report No. 49
AQUATIC PRIMARY PRODUCTIVITY AND
PHYSICAL-CHEMICAL LIMNOLOGY ON THE PAWNEE SITE

GRASSLANDS BIOME
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ABSTRACT

Monthly measurements of community primary productivity, planktonic primary productivity, and physical-chemical parameters have begun on the Pawnee Site. Preliminary data are reported and trends are beginning to appear, particularly in reference to physical-chemical changes of a seasonal nature.

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INTRODUCTION

This report describes materials and techniques being employed monthly to measure primary productivity and physical-chemical parameters in selected aquatic habitats on the Pawnee Site during 1970. Specific objectives, methods, preliminary results, and future analyses are given for each of the three integrated phases of this aquatic research: community primary productivity, planktonic primary productivity, and physical-chemical aspects.

DESCRIPTION OF STUDY AREA

Four diverse lentic habitats are being studied extensively and can be located in Fig. 1. Specific map locations for each aquatic site is as follows:

Cottonwood Pond	T10N/R66W/S14
Spring Pond	T10N/R65W/S8&17
Lake George	T10N/R65W/S5&8
Lynn Lake	T10N/R66W/S23

Cottonwood Pond is a .4 hectare, crescent-shaped pond with an average depth of .5 m. It is a permanent, spring-fed pond located south of the main channel of Little Owl Creek. It probably developed as an oxbow cutoff from the main channel of Little Owl Creek.

Spring Pond is a .3 hectare, cigar-shaped pond in the main channel of an intermittent stream. Its average depth is .5 m, however, one location on the northeast end is about 1.4 m deep. It is flushed out periodically by water flowing down the main channel of the intermittent stream. Spring Pond is also fed by ground water from a spring in its upper end.

Lake George is a playa lake with a surface area 20.2 hectares and an average depth of .4 meters when full. Since the only source of water for Lake George is runoff, the volume of water fluctuates typically from 0 to 13,130 m³ according to annual precipitation amounts.

Lynn Lake is also a playa lake, but of a different nature. The slope of its surrounding basin is steeper than that of Lake George. Periods in which water fills the bowl-like basin are relatively short, and are wholly dependent upon localized precipitation. Morphometric data have been collected for this habitat and are available at the Natural Resource Ecology Laboratory.

PHASE 1: COMMUNITY PRIMARY PRODUCTIVITY

OBJECTIVES OF SAMPLING

The major objective was to obtain comparative estimates of primary productivity in ponds on the Pawnee Site. Another objective was to develop an instrumentation system for monitoring and recording diurnal changes in dissolved oxygen of the ponds. The diurnal oxygen curve method will then be compared with the ^{14}C and CO_2 methods for measuring primary productivity. The primary productivity information will eventually be used in modeling energy flow in the grassland aquatic system and in making comparisons to terrestrial primary productivity.

MATERIALS AND TECHNIQUES

Oxygen content is a property of natural waters which shows considerable fluctuation from time to time. It may vary with depth or horizontally according to the distribution of plant materials in the water. While the light-driven photosynthetic process and the respiratory metabolism of organisms in the water may account for the major changes in the dissolved oxygen content, temperature, altitude, diffusion rates, water chemistry, inflow of subsurface water, and mixing action must also be considered.

Many methods have been proposed and used to measure changes in the diurnal oxygen content of lentic habitats. These basically fall into three

categories: (1) enclosing a portion of the water in glass or plastic and measuring oxygen changes; (2) ^{14}C uptake methods; (3) measuring dissolved oxygen uptake *in situ*. These methods are all discussed by Talling (1969).

For monitoring purposes on the Pawnee ponds the measurement of dissolved oxygen *in situ* seems to be the preferable method. The main reason for this choice is that oxygen concentration may be measured electronically with a dissolved oxygen probe rather than by chemical means.

Recording preliminary data from Cottonwood Pond and Spring Pond was done with a Rustrak Model 192 DO/Temperature Recorder. A more sophisticated system for continuous monitoring has been designed and proposed for later work (see specifications prepared by Colspan, Inc.). The Rustrak system records on a paper strip chart while the Colspan "pondsonde" system records telemetered data on a punched paper tape system which can later be automatically reduced for data processing.

Calculation of the January and February dissolved oxygen curves were simplified because the ice cover on the ponds made a natural, enclosed system. Variables such as diffusion, mixing action due to wind, and changes in water temperature could be eliminated from the calculations because of the ice cover. The static conditions under the ice were not initially apparent until continuous monitoring of the system was attempted. Natural melting of holes near the edge of the pond and walking on the ice to collect hourly samples caused a distortion of the thermal stratification in the shallow ponds.

A sample calculation from the 23 January 1970 data on Cottonwood Pond (Table 1) is shown in the following steps.

1. The percent oxygen saturation is calculated according to a procedure outlined by American Public Health Assoc., Inc. Standard Methods (1960). Results appear in Table 1.

2. A graph of the percent oxygen saturation vs. time is constructed as shown in Fig. 2. The shaded portion of the graph represents the time from sunset to sunrise.
3. The area under the diurnal oxygen curve is determined for the dark period and the light period. This may be done with a planimeter or by making the curve on uniform density paper and removing the paper under the curve so that it can be weighed on an analytical balance.
4. The area of the diurnal oxygen curve during darkness represents a decrease in dissolved oxygen due to respiration of organisms in the pond. This dark area is subtracted from the area under the light portion of the curve to yield "net" production of oxygen for 24 hours. The calculation may be summarized by $Q=P-R$ where Q = net primary productivity, P = gross primary productivity and R = respiration.
5. Since the net primary productivity value thus obtained represents the oxygen produced in a column of water 1 m^2 and as deep as the pond, it is necessary to correct the net primary productivity value for the depth of the pond where the measurement was being made (.6 m in Cottonwood Pond). This then yields the net primary productivity value in $\text{g oxygen/m}^2/24\text{ hour}$.
6. The "24 hour" net primary productivity value may be converted to "hourly" productivity by dividing by 24. This gives values expressed as $\text{g/m}^2/\text{hour}$. The g may represent either grams carbon being fixed or grams of oxygen being produced.

PRELIMINARY RESULTS

Preliminary measurements of primary productivity in Spring and Cottonwood Ponds were made 23 January and 13 February 1970 using the diurnal oxygen curve method. During this time both ponds were covered with ice 11 to 16 cm in thickness.

Net primary productivity in Cottonwood ranged from $.19 \text{ g/m}^2/\text{hour}$ in January to $.01 \text{ g/m}^2/\text{hour}$ in February. In Spring Pond the range was from $.25 \text{ g/m}^2$ in January to 0.0 in February.

These data compare favorably with productivity recorded for other eutrophis, standing water bodies under similar conditions. Since net primary productivity is zero at times under the ice cover, anaerobic conditions are probably common in winter especially on cloudy days.

FUTURE ANALYSIS

Monthly primary productivity measurements will be continued. Light measurements and calculation of photosynthetic efficiency will be incorporated in future reports. Additional refinement of instrumentation and techniques will be continued.

PHASE II: PLANKTONIC PRIMARY PRODUCTIVITY

OBJECTIVES OF SAMPLING

The objectives of the present investigation are:

1. To quantify the annual primary productivity of selected aquatic habitats on the Pawnee Site.
2. To describe the seasonal variation in primary productivity of selected aquatic habitats on the Pawnee Site.

3. To investigate other temporal (daily and hourly) and spatial (vertical and horizontal) factors which influence measurements of primary productivity.

MATERIALS AND TECHNIQUES

The ^{14}C technique for measuring primary productivity of phytoplankton, first described by Steemann Nielsen (1952), is based upon the assumption that a constant relationship exists between the assimilation of stable carbon and the assimilation of radioactive carbon added in small quantities. This relationship is expressed by the formula:

$$\frac{{}^{12}\text{C}_{\text{ assimilated}}}{{}^{12}\text{C}_{\text{ available}}} = \frac{{}^{14}\text{C}_{\text{ assimilated}}}{{}^{14}\text{C}_{\text{ available}}}$$

Steemann Nielsen (1958) pointed out that if the amount of organically bound ^{14}C in the plankton after an experiment is to give an absolute measure of the intensity of photosynthesis the following conditions must be satisfied:

1. $^{14}\text{CO}_2$ must be incorporated in organic compounds only through photosynthesis.
2. The rates of assimilation of $^{14}\text{CO}_2$ and $^{12}\text{CO}_2$ must be the same.
3. $^{14}\text{CO}_2$ must not be lost through respiration, which occurs simultaneously with photosynthesis.
4. Organic matter must not be lost by excretion.

Although none of the above conditions are completely fulfilled in the ^{14}C technique, Steemann Nielsen (1958) has shown that a total correction of only 10% is necessary when the rate of respiration is less than 10% of the photosynthetic rate. The ^{14}C technique is believed to yield a value which lies

somewhere between gross and net primary productivity, and is probably closest to the latter (Strickland 1960).

Sampling Procedures

Water samples were collected from depths at which bottles were to be incubated *in situ*. Glass-stoppered B.O.D. bottles, which varied closely to 302 ml, were filled in series of three (two "light" bottles and one "dark" bottle). Dark bottles were made opaque by successively covering them with: two coats of black enamel, two layers of Scotch No. 33 black, acid-proof electrical tape, and two more coats of black enamel. Once filled, the bottles were "spiked" with 5 μ c of ^{14}C , stoppered, and the tops covered with aluminum foil. The three bottles were then suspended in a vertical position at the depth from which the water sample was taken.

One series of bottles was incubated from dawn to mid-day and another series was incubated from mid-day to dusk. Three ml of neutral formalin were added to each bottle at the end of the incubation period and the bottles were taken to the laboratory for filtration.

Varying amounts of the contents of each bottle (depending upon the abundance of plankton and seston) were filtered through an HA Millipore filter (0.45 μ pore size) under vacuum. Filters were then washed with 10 ml of a 0.001 N hydrochloric acid solution to remove any unfixed ^{14}C from the filter. Each filter disc was sucked free of all excess liquid, removed from the filtration apparatus, and cemented to a stainless steel planchet which had been coated previously with rubber cement. Filters were stored in desiccators over anhydrous calcium sulfate until they were counted after drying for a period of 48 or more hours.

Counting Procedures

All filters were counted for 10 or more minutes in a Baird-Atomic window gas flow abacus GM scaler, model 123B which had a mean efficiency of 23.4%. A minimum of 1000 and 300 counts per minute were obtained for light and dark bottle samples, respectively. The stability of the counting system was checked before its use each day. No correction for self-absorption was made as the weight of the residue on the filters was less than 0.1 mg/cm^2 .

Calculation of $\text{mg C/m}^3/\text{hour}$

Formulae used for the calculation of $\text{mg C/m}^3/\text{hour}$ in the present investigation were as follows:

$$(1) \text{ Net cpm} = \frac{\text{Mean LB cpm} - \text{DB cpm}}{\text{Machine efficiency}}$$

$$(2) {}^{14}\text{C fixed} = \frac{\text{Net cpm}}{\text{cpm added}}$$

$$(3) {}^{14}\text{C fixed}/\ell/\text{hour} = \frac{{}^{14}\text{C fixed}/\ell}{\text{Hours of incubation}}$$

$$(4) \text{ Total mg } {}^{12}\text{C}/\ell \text{ available} = a + b$$

$$a = \text{mg CO}_2/\ell \times \frac{12}{44}$$

$$b = \text{mg HCO}_3/\ell \times \frac{12}{61}$$

$$(5) \text{ mg } {}^{12}\text{C fixed}/\text{m}^3/\text{hour} = {}^{14}\text{C fixed}/\ell/\text{hour} \times \text{t.a. } {}^{12}\text{C} \times 1000$$

No correction for the isotope effect was made inasmuch as the corrections in the literature are variable and uncertain. Stock ampules of $\text{NaH}^{14}\text{CO}_3$ with an activity of 5 μC were obtained commercially and used in all experiments and in the preparation of ${}^{14}\text{C}$ standards for counting.

PRELIMINARY RESULTS

Although samples for January and February have been initially counted, the results have not yet been converted to meaningful values of primary productivity. It is anticipated that a more efficient counting system will be developed shortly with the possibility of converting over to a liquid scintillation counting system.

FUTURE ANALYSIS

The ^{14}C analysis of primary productivity will be expanded in the summer of 1970 to look at other temporal (daily and hourly) and spatial (vertical and horizontal) factors which influence measurements of primary productivity.

PHASE III: PHYSICAL-CHEMICAL ASPECTS

OBJECTIVES OF SAMPLING

The objectives of the present investigation are to:

1. Characterize each habitat chemically and physically during each month.
2. Correlate physical-chemical data with phytoplankton and/or zooplankton pulses.
3. Contribute chemical data necessary in primary productivity estimations.

MATERIALS AND TECHNIQUES

Eight primary limnological parameters are determined in the field each month: temperature, dissolved oxygen, pH, turbidity, P - alkalinity, T - alkalinity, total hardness, and calcium hardness. All eight of these variables are measured using a Hach Model DR-EL Portable Engineer's Laboratory. In the laboratory analyses are made for such variables as ΣFe , SiO_2 , Ca^{+2} , Mg^{+2} , SO_4^{-2} ,

Cl^- , Na^+ , K^+ , Mn , Mo , Zn^{+2} , NO_2^- , NO_3^- , and ΣPO_4 . Specific procedures as outlined in Golterman (1969) and Standard Methods (1965) are employed. Spectrophotometric analyses of selected cations are determined using either a Beckman Flame Spectrophotometer Model 109200 DU-2 or a Beckman Atomic Absorption Spectrophotometer Model DB-G, depending on specific sensitivities.

PRELIMINARY RESULTS

Each of the four habitats under consideration has a separate table of physico-chemical parameters (Tables 2, 3, 4, and 5). Each primary parameter is discussed below.

1. *Temperature.* Seasonal variations of surface water temperatures were evident for both Spring Pond and Cottonwood Lake. On two occasions Lake George was nothing more than a frozen block of ice overlying a mud flat. Whenever Lynn Lake contained water, it tended to increase in temperature during the summer of 1969.
2. *Dissolved oxygen.* Surface values of dissolved oxygen in Spring Pond and Cottonwood Pond were erratic, particularly during open water months. But, generally a decrease in dissolved oxygen occurred during period of snow and ice cover for Spring, Cottonwood, and George. Lynn Lake on three occasions showed a dissolved oxygen content of approximately 2.9 ppm.
3. *Hydrogen ion concentration.* The pH of all sites (except Lynn Lake on 17IX69) was either neutral or decidedly alkaline for this study period. The range in pH for each pond was as follows:

Spring Pond	- 8.2 to 10.0
Cottonwood Lake	- 7.0 to 9.8
Lake George	- 7.0 to 8.5
Lynn Lake	- 6.7 to 7.7

4. *Turbidity*. High turbidity values were always evident for the two exposed temporary ponds. The deeply cut banks of Spring Pond and the lush emergent vegetation of Cottonwood Pond prevent extensive turbulence. In order of decreasing mean turbidity values the four habitats could be listed as follows:

Lynn Lake
Lake George
Spring Pond
Cottonwood Lake

5. *Alkalinity*. The T-alkalinity of the four habitats ranged from 20 ppm (Lynn Lake) to 620 ppm (Spring Pond). During periods of extensive autotfixation in Spring Pond, Lake George, and Cottonwood Pond carbonate alkalinities were evident. Bicarbonate alkalinity was the principal contributing form at most times at all sites.
6. *Hardness*. Calcium hardness of the four sites ranged from 11 ppm (Lynn Lake) to 280 ppm (Lake George). Cottonwood Pond had values of calcium hardness in excess of 200 ppm for six winter months. Magnesium hardness values (total hardness minus calcium hardness) were quite variable and should be calculated from Tables 2, 3, 4, and 5. Total hardness values for all sites were a reflection of prior periods of dilution by precipitation.

FUTURE ANALYSIS

Further spectrophotometric analyses will be made for various minor and trace elements in each habitat. Such elements may significantly influence primary productivity values.

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Table 1. Cottonwood Pond Data, January 23, 1970.

Date	Time	Water Temp. ^{1/} at 10 cm. (oc)	Dissolved O ₂ (ppm)	%O ₂ Saturation (calculated)	Remarks
23II70	0600	1.0	5.9	43	
	0723				Sunrise
	0730	1.0	6.0	44	
	0830	0.7	5.2	38	
	0930	1.0	4.8	35	Cloudy Sky
	1055	2.0	4.0	30	
	1130	3.0	4.8	36	
	1200	3.0	4.6	34	
	1330	3.0	6.8	52	
	1445	3.0	7.2	55	
	1545	3.0	9.6	73	
	1700	2.0	7.8	58	Sundown (1704)
	1945	2.0	7.4	54	
	2300	4.0	4.2	33	
24II70	0600	2.0	4.0	29	

^{1/} It has been found subsequently that water temperature under the ice in Cottonwood remains more constant than these data show. Mixing with warmer bottom water was caused by people walking on the ice surface to obtain samples.

Table 2. Preliminary physico-chemical characteristics of Cottonwood Pond.

NAME	DATE	TIME	TEMP. (°C.)	DO ₂ (ppm)	pH	TURBIDITY (JTU)	ALKALINITY P-alk. (ppm)	T-alk. (ppm)	TOTAL HARDNESS (ppm)	Ca HARDNESS
Cottonwood Pond										
28IX68	0945	10.5	7.0	3.0	7.0	3.0	0.0	250.0	204.0	160.0
23XI68	0100	3.0	8.2	64.0	8.4	64.0	0.0	230.0	300.0	250.0
*11XII68	0330	4.5	7.3	2.0	8.3	2.0	0.0	236.0	305.0	202.0
*25I69	1115	1.0	0.0	4.0	7.4	4.0	0.0	300.0	300.0	230.0
*22II69	1100	1.0	1.0	25.0	8.2	25.0	0.0	320.0	310.0	230.0
27III69	1000	5.0	9.4	15.0	7.8	15.0	0.0	285.0	350.0	240.0
25IV69	1030	7.5	4.4	10.0	8.1	10.0	0.0	230.0	270.0	150.0
29V69	1315	26.0	6.0	0.0	8.5	0.0	49.0	143.0	117.0	35.0
27VI69	1200	21.0	4.4	0.0	7.9	0.0	39.0	148.0	132.0	47.0
30VII69	1115	18.0	1.4	2.0	8.5	2.0	0.0	238.0	176.0	116.0
18VIII69	1115	23.0	4.0	5.0	9.8	5.0	10.0	114.0	91.0	42.0
17IX69	1400	18.5	3.8	3.0	8.6	3.0	0.0	147.0	131.0	70.0
25X69	1050	7.0	4.6	17.0	7.6	17.0	0.0	196.0	256.0	169.0
12XI69	1236	4.5	4.8	5.0	8.5	5.0	0.0	227.0	267.0	176.0
*10XII69	0930	1.5	8.0	0.0	8.4	0.0	0.0	310.0	317.0	239.0
*23I70	0615	1.0	5.9	0.0	8.4	0.0	0.0	219.0	215.0	161.0
*14II70	1900	3.0	6.2	8.0	7.4	8.0	0.0	260.0	250.0	186.0

*Complete ice cover

Table 3. Preliminary physico-chemical characteristics of Spring Pond.

NAME	DATE	TIME	TEMP. (°C)	DO ₂ (ppm)	pH	TURBIDITY (JTU)	ALKALINITY		TOTAL HARDNESS (ppm)	Ca HARDNESS
							P-alk. (ppm)	T-alk. (ppm)		
Spring Pond										
	23XI68	1200	5.0	7.2	8.6	140.0	0.0	310.0	120.0	60.0
	*11XII68	0230	3.0	7.2	8.8	22.0	0.0	620.0	140.0	80.0
	*25I69	1600	2.0	3.6	8.4	47.0	0.0	620.0	170.0	90.0
	*22II69	1100	1.0	1.0	8.2	30.0	0.0	510.0	120.0	80.0
	27III69	1400	6.5	10.0	8.4	42.0	0.0	465.0	120.0	70.0
	25IV69	0930	0.0	4.8	8.5	54.0	65.0	494.0	100.0	40.0
	29V69	1400	22.0	2.8	8.5	25.0	61.0	538.0	88.0	38.0
	27VI69	1400	16.0	5.0	8.7	52.0	56.0	207.0	55.0	36.0
	30VII69	1300	22.5	3.6	8.7	32.0	52.0	246.0	43.0	22.0
	18VIII69	1030	21.0	2.0	10.0	50.0	49.0	302.0	44.0	20.0
	17IX69	1540	18.5	3.0	9.9	77.0	54.0	415.0	96.0	66.0
	25X69	1212	9.0	5.6	8.5	62.0	31.0	393.0	104.0	54.0
	12XI69	1435	6.0	5.2	9.1	62.0	26.0	392.0	109.0	54.0
	*10XII69	0845	2.5	3.6	9.2	57.0	25.0	462.0	116.0	50.0
	*23I70	0720	0.0	7.0	8.6	57.0	0.0	439.0	139.0	79.0
	*14II70	1930	4.0	9.0	9.2	40.0	35.0	425.0	104.0	53.0

*Complete ice cover

Table 4. Preliminary physico-chemical characteristics of Lake George.

NAME	DATE	TIME	TEMP. (°C)	DO ₂ (ppm)	pH	TURBIDITY (JTU)	ALKALINITY		TOTAL HARDNESS (ppm)	Ca HARDNESS
							P-alk. (ppm)	T-alk. (ppm)		
Lake George										
	28IX68	0610	12.0	3.7						
	28IX68	1200	13.2	6.2		550.0	0.0			
	23XI68	1045	4.0	5.2	8.3	600.0	0.0	180.0	170.0	120.0
	*11XII68	0130	0.0	8.1	8.5	350.0	0.0	220.0	188.0	120.0
	*25I69	1500	0.0	0.0	7.1	160.0	0.0	560.0	530.0	280.0
	*22II69	1300	1.0	1.2	7.0	650.0	0.0	273.0	200.0	159.0
	27III69	1230	12.5	9.2	8.0	120.0	0.0	170.0	165.0	110.0
	25IV69	**	**	**	**	**	**	**	**	**
	29V69	1445	27.0	2.8	8.5	137.0	19.0	100.0	103.0	90.0
	27VI69	1300	16.0	2.4	8.3	498.0	0.0	140.0	124.0	107.0
	30VII69	1245	20.5	3.0	8.4	345.0	0.0	237.0	206.0	163.0
	18VIII69	0930	18.5	3.4	Ind.	600.0	0.0	232.0	183.0	133.0
	17IX69	**	**	**	**	**	**	**	**	**
	25X69	**	**	**	**	**	**	**	**	**
	12XI69	**	**	**	**	**	**	**	**	**
	10XII69	**	**	**	**	**	**	**	**	**
	23I70	**	**	**	**	**	**	**	**	**
	14II70	**	**	**	**	**	**	**	**	**

*Complete ice cover

**Lake basin dry

Table 5. Preliminary physico-chemical characteristics of Lynn Lake.

NAME	DATE	TIME	SURF.		DO ₂ (ppm)	pH	TURBIDITY (JTU)	ALKALINITY		TOTAL HARDNESS (ppm)	Ca HARDNESS
			TEMP. (°C)					P-alk. (ppm)	T-alk. (ppm)		
Lynn Lake											
	28IX68		**		**	**	**	**	**	**	**
	23XI68		**		**	**	**	**	**	**	**
	11XII68		**		**	**	**	**	**	**	**
	25I69		**		**	**	**	**	**	**	**
	25II69		**		**	**	**	**	**	**	**
	27III69		**		**	**	**	**	**	**	**
	25IV69		**		**	**	**	**	**	**	**
	29V69		**		**	**	**	**	**	**	**
	27VI69	1050	12.9		2.6	7.7	600.0	0.0	24.0	32.0	22.0
	30VII69	1030	19.0		Ind.	7.0	600.0	0.0	31.0	92.0	67.0
	18VIII69		**		**	**	**	**	**	**	**
	17IX69	1300	25.5		2.4	6.7	500.0	0.0	25.0	30.0	14.0
	25X69	1015	6.0		3.8	7.1	58.0	0.0	20.0	17.0	11.0
	12XI69		**		**	**	**	**	**	**	**
	10XII69		**		**	**	**	**	**	**	**
	23I70		**		**	**	**	**	**	**	**
	14II70		**		**	**	**	**	**	**	**

**Lake basin dry

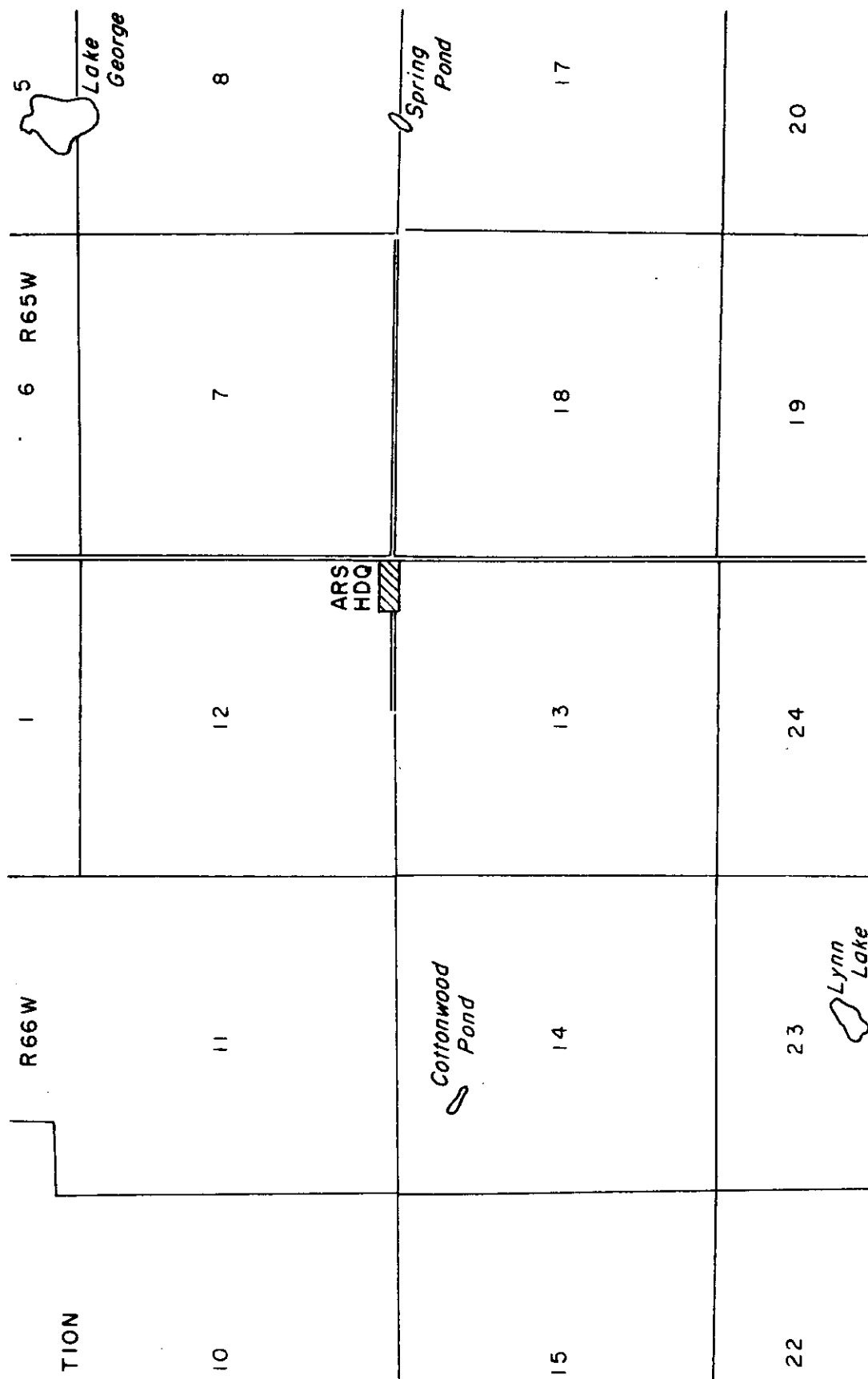


Fig. 1. Location of lentic habitats.

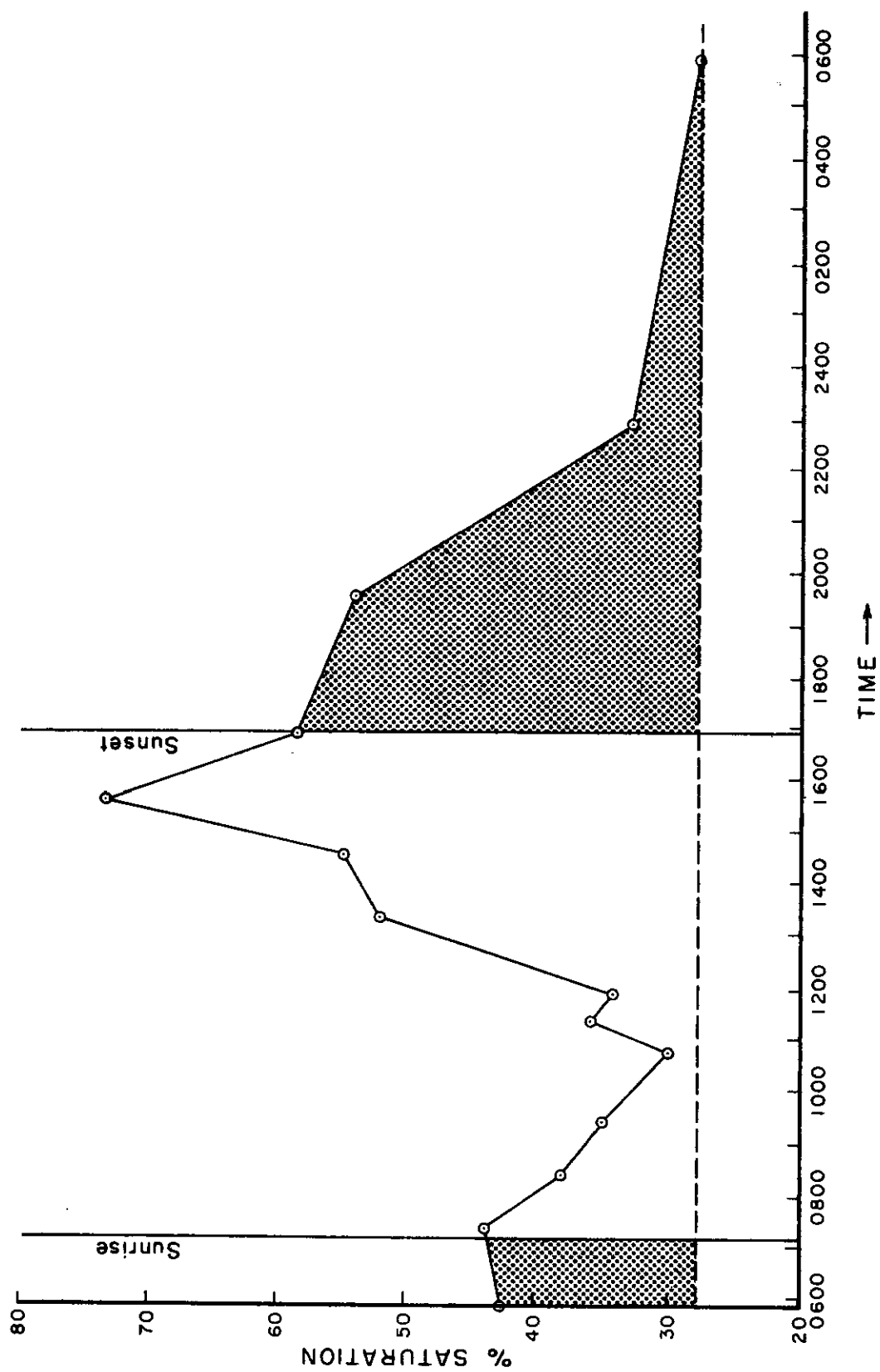


Fig. 2. Diurnal dissolved oxygen curve for Cottonwood Pond 23 Jan. 1970.