

COMMUNITY METABOLISM IN LOWER PEORIA LAKE

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ABSTRACT. — The diurnal oxygen curve method of measuring community metabolism was used to study primary production and community respiration in the Illinois River from June to September, 1968. Readings of temperature, conductivity, alkalinity, pH, turbidity, chlorophyll *a* content, and the euphotic zone were taken at regular intervals. Light intensity was recorded simultaneously with each diurnal and photosynthetic efficiency was computed.

flux of organic matter in order to maintain the community.

DESCRIPTION OF STUDY AREA

The stretch of river studied lies between mile 162.7 and mile 165.7 above the confluence of the Illinois and Mississippi Rivers (Fig. 1). This stretch of the river is approximately 3.0 miles in length and is called Lower Peoria Lake because of the river's natural widening at this point. The Illinois River is a very sluggish, silt laden, and enriched river which arises in Cook County and empties into the Mississippi River at Grafton, Illinois some 434 miles downstream. The silt load has been increasing since 1900 due to farming practices and to sewage and industrial outfall. At the same time, the river's rate of flow has been decreased by the building of a number of locks and dams.

Much work has been done on the extent and types of pollution in the Illinois River, but little has been recorded on the effects of this pollution on community metabolism.

Knowledge of community metabolism enables a better understanding of the aquatic community. Community metabolism involves production and respiration of oxygen by the community. For every gram of oxygen produced, approximately one gram of synthesized carbohydrate material is added to the aquatic community. Conversely, approximately one gram of oxygen is required for each gram of carbohydrate respired. Organic matter will accumulate in a community when production exceeds respiration as at Silver Springs, Florida, (Odum, 1957). When respiration exceeds production, however, there must be a constant in-

Lower Peoria Lake was selected for the study area because it is believed to be one of the cleanest stretches of the Illinois River. Much of the effluent from Chicago and other communities upstream has had sufficient time to be degraded by the time it reaches Peoria. In addition, industrial and sewage outfall from

the Peoria-Pekin area enters the river further downstream.

PROCEDURES

Two collection stations approximately three miles apart were established at opposite ends of the lake. (Fig. 1). Water samples for determination of physico-chemical conditions were taken approximately once a week at a depth of three feet to counteract wind and wave action. Water temperature was measured with a mercury thermometer. Conductivity was measured with a YSI Model 31 Conductivity Bridge at 25 C. Turbidity was measured in the laboratory with a Bausch and Lomb Spectronic 20 colorimeter with a 2.54 cm cuvette at d_{430} . A Sargent pH meter was used for pH determinations. Methyl orange and phenolphthalein alkalinity were de-

termined in the field by titration with 0.02N sulphuric acid.

Water samples of 100 ml were filtered through membrane filters of 0.45 micron pore size for suspended chlorophyll analysis. The residues were extracted in 10 ml of 90% acetone for 24 hours at 5 C and centrifuged. Optical density was read at 665 millimicrons and 430 millimicrons on a Bausch and Lomb Spectronic 20 colorimeter. The methods of Odum, McConnell and Abbott (1958) were used to estimate chlorophyll *a* concentration where chlorophyll *a* in mg/liter of 90% acetone equals $13.4 d_{665}$. When corrected for acetone and sample volume, this equation became $1.34 d_{665}$.

Depth of light penetration was determined with a G. M. Mfg. Instrument Corporation submarine photometer. The euphotic zone was considered to extend to a depth at which light was 1% of surface intensity. A bimetallic actinograph kept at Bradley University measured solar radiation on days when community metabolism was measured.

Gross photosynthesis and respiration were computed from diurnal changes in concentration of dissolved oxygen according to the procedure of Odum and Hoskin (1958) and Copland and Dorris (1962). Duplicate water samples were taken every two hours in daylight and every three hours at night at both stations and analyzed for oxygen by the Alsterberg (Azide) modified Winkler method.

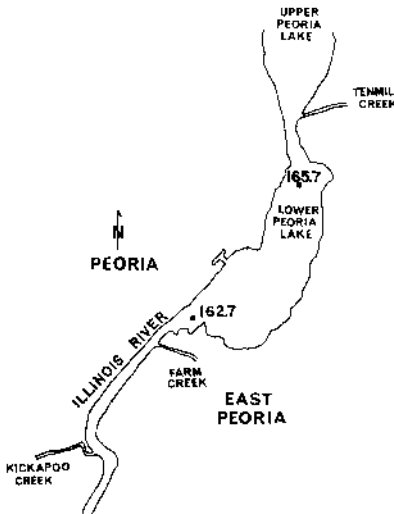


FIGURE 1. Map of Peoria Lake and the Illinois River near Peoria. Station locations are indicated by numerals. North Station = 165.7; South Station = 162.7.

RESULTS AND DISCUSSION

Physico-Chemical Conditions

In most cases, mean summer

TABLE 1.—Mean Summer Physico-Chemical Conditions in Lower Peoria Lake.

Station	Temperature (C)	Turbidity (ppm)	Specific Conductance (umhos/cm)	Alkalinity		Dissolved Oxygen (ppm)	pH
				HCO ₃ ⁻ (ppm)	CO ₃ ⁼ (ppm)		
North.....	25	66	540	179	0	6.4	8.0
South.....	25	67	539	179	0	7.9	8.2

physico-chemical conditions between stations were slight and insignificant (Table 1). Daily variation in water temperature was generally not more than 3 C while the seasonal variation ranged from 20 to 30 C. Alkalinity was due exclusively to bicarbonates.

Specific conductance ranged from 429 to 595 micromhos/cm. Conductivity below 537 micromhos/cm was not recorded except for a two week period when the river level was above normal due to heavy rains. The low readings may be attributed to dilution of river water by increased volume of runoff water.

The pH varied from 7.5 to 8.7. Most readings were above 8.0. Free carbon dioxide is absent or present in very low concentrations above pH 8.0. This may limit photosynthesis for some algae and higher plants while others are able to obtain their carbon dioxide from bicarbonates (Duffer, 1965).

Downstream pH values were always higher than upstream values with a single exception. Dissolved oxygen was also consistently higher at the South Station.

Turbidity ranged from 39 to 135 ppm during the study (Fig. 2). Highest turbidity observed was during a period of abnormally high flow in June.

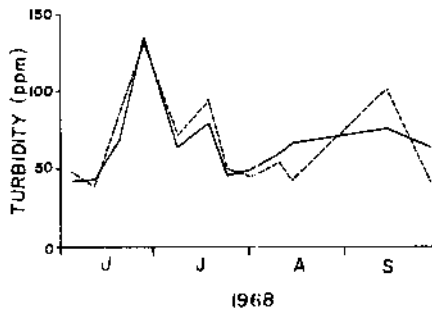


FIGURE 2. Turbidity conditions in Peoria Lake (—) = North Station; (---) = South Station.

Chlorophyll *a* concentrations varied from 0.07 mg/l to 0.40 mg/l (Fig. 3). This parameter was converted to gr/m² by taking the prod-

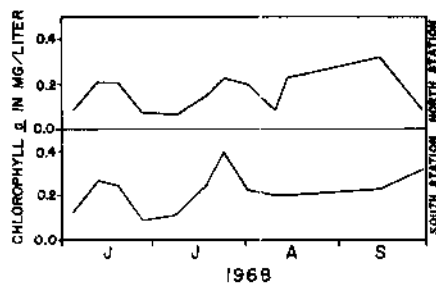


FIGURE 3. Chlorophyll *a* concentration in Peoria Lake.

uct of chlorophyll *a* concentration in gr/m^3 and the euphotic zone (Fig. 4). Mathis, Root, and Weiman (1968) reported chlorophyll *a* concentrations in the Illinois River ranging from 0.03 to 0.50 mg/l . These concentrations are within the range of ecosystems receiving organic enrichment.

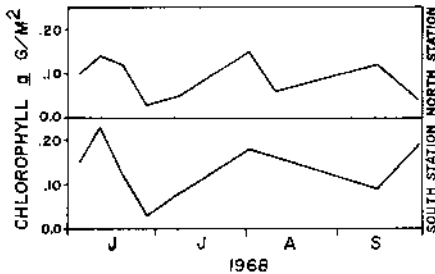


FIGURE 4. Chlorophyll *a* concentration in gm/m^2 in Peoria Lake.

The ratios of plant pigment absorbancies (D_{430}/D_{665}) are given in figure 5. Margalef (1963) used this ratio as a means of determining succession. As succession advances, the index increases. In general, the ratios for this study were near 3.0 except when the community was disturbed by high water conditions.

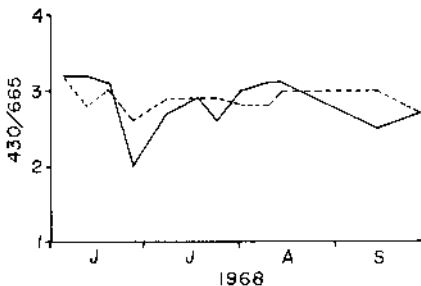


FIGURE 5. Margalef pigment ratios in Peoria Lake. (—) = North Station; (---) = South Station.

The ratios returned to around 3.0 shortly after normal flow conditions were re-established. Fluctuations in the pigment ratio were not so marked at the South Station indicating that it was probably less affected by environmental changes.

Community Metabolism

Eight diurnal analyses were performed at each station during this study. Flow rates were computed for each of those days and ranged from 10 hours on 28 June 1968 to 38 hours on 15 September 1969 (T. Butts, unpublished data). Primary productivity and community respiration were plotted for days with clear skies. Lowest production occurred at both stations during a time of high water, increased rate of flow and greatly increased turbidity. Gross photosynthesis ranged from 1.6 $\text{gm O}_2/\text{m}^2/\text{day}$ on 28-29 June to 13.8 $\text{gm O}_2/\text{m}^2/\text{day}$ on 6-7 June at the North Station (Fig. 6). Respiration at the North Station varied from 3.7 $\text{gm O}_2/\text{m}^2/\text{day}$ on 15-16 September to 18.2 $\text{gm O}_2/\text{m}^2/\text{day}$ on 6-7 June.

At the South Station, production ranged from a low of 2.0 $\text{gm O}_2/\text{m}^2/\text{day}$ on 28-29 June to a high of 12.5 $\text{gm O}_2/\text{m}^2/\text{day}$ on 6-7 June. Respiration ranged from 3.1 $\text{gm O}_2/\text{m}^2/\text{day}$ on 15-16 September to 13.8 $\text{gm O}_2/\text{m}^2/\text{day}$ on 29-30 July. Community metabolism in other aquatic communities calculated from diurnal oxygen curves is presented in Table 2.

Productivity in Peoria Lake is undoubtedly affected by the turbidity which in turn determines the euphotic zone (Table 3). The euphotic zone was generally deeper during

TABLE 2. Community metabolism in selected aquatic communities calculated from diurnal oxygen curves.

Source	g O ₂ /m ² /day	
	P	R
Eleven Florida Springs, summer (Odum, 1957)	0.68-63.8	
Blue River, Oklahoma, summer (Duffer and Dorris, 1966)	3.3-48.0	6.1-19.9
Skeleton Creek, Oklahoma, summer (Baumgardner, 1966)	4.2-29.4	17.0-57.1
San Marcos River, Texas, spring and summer (Hannan, 1967)	2.5-27.4	4.1-19.9
Illinois River (Present study)	1.6-13.8	3.1-18.2

periods of low flow. Following heavy rains, however, the depth of the euphotic zone was minimal.

Photosynthetic Efficiency

The efficiency of algae in utiliz-

TABLE 3. Depth of euphotic zone in meters.

Date	Station	
	North	South
6 June	1.14	1.14
13 June	.69	.87
20 June	.56	.48
28 June	.33	.33
19 July	.76	.76
19 July	.58	.47
29 July	.88	.77
2 August	.77	.78
11 August	.70	.78
15 Sept.	.39	.39
29 Sept.	.46	.60
Mean	.66	.67

ing solar radiation for conversion to chemical energy was computed from gross photosynthesis and radiation data. Solar radiation was measured on five occasions and varied from a high of 674 cal/cm²/day on 28-29 June, to a low of 495 cal/cm² on 15-16 September (Table 4). Efficiency was calculated according to the equation:

TABLE 4.—Photosynthetic Efficiency in Lower Peoria Lake.

Date	Station	Photo-synthesis gm/m ² /day	Chlorophyll <i>a</i> gm/m ²	Photo-synthetic Efficiency %	Total Solar Radiation cal/cm ² /day
28-29 June	North	1.6	0.03	0.08	674
	South	2.0	0.03	0.10	
10-11 July	North	3.2	0.05	0.17	673
	South	4.3	0.08	0.22	
19-20 July	North	2.6	0.09	0.14	671
	South	4.3	0.12	0.22	
29-30 July	North	12.3	0.18	0.84	515
	South	12.4	0.18	0.84	
15-16 September	North	3.1	0.12	0.22	495
	South	2.2	0.09	0.16	

$$\text{Photosynthetic efficiency} = \frac{(0.35) (\text{gm } O_2/\text{m}^2/\text{day}) 100}{\text{solar radiation } (\text{cal.}/\text{m}^2/\text{day})}$$

This is assuming that 3,500 gram calories of solar radiation are required for each gram of oxygen. For the present study, a value of 50% light utilization was assumed (Ryther, 1956).

Efficiency was rather low and ranged from 0.10% to 0.84%.

Baumgardner (1966) obtained values ranging from 0.48% to 6.42% in polluted Skeleton Creek, Oklahoma. Copeland and Dorris (1964) reported efficiencies ranging from 0.0% to 3.9% in oil refinery effluent holding ponds. Efficiencies for undisturbed ecosystems are generally higher. Odum and Odum (1955) reported an efficiency of 6.0% for Eniwetok Atoll and Odum (1957) reported efficiencies up to 10% for eleven Florida Springs. In a study of two unpolluted southwestern streams Duffer and Dorris (1966) reported efficiencies ranging from 0.2% to 5.4% while Hannan (1967) reported a range of 0.2% to 4.8%. The greater diversity of flora in more highly balanced ecosystems is apparently the reason for the higher efficiencies. Algae in the Illinois River exhibited efficiencies similar to those observed in oil refinery effluent holding ponds in that both communities tended to utilize energy less efficiently than did algae in undisturbed systems.

Production/Respiration Ratio

The ratio of productivity to respiration provides a meaningful index by which flowing aquatic communities may be classified (Odum,

1956). When oxygen production exceeds demand, organic matter accumulates faster than it can be used and the community is said to be autotrophic. When oxygen demand exceeds production, organic matter is utilized faster than it can be produced and the community is said to be heterotrophic. In the later case, organic matter must be imported into the community if it is to survive. On only one occasion was the oxygen production greater than the oxygen utilization, and in general, the production to respiration values were low (Fig. 6).

The P/R ratio was generally higher at the South Station (Fig. 7). This was apparently due to greater

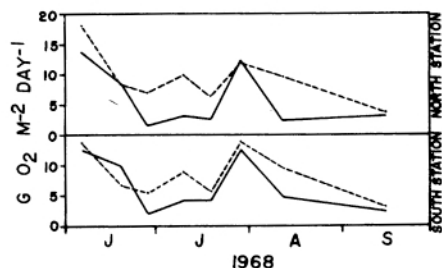


FIGURE 6. Community metabolism in Peoria Lake. (—) = Production; (---) = Respiration.

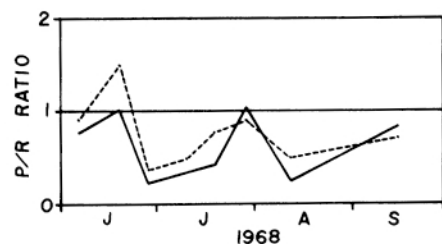


FIGURE 7. Photosynthesis/Respiration ratios of community metabolism in Peoria Lake. (—) = North Station; (---) = South Station.

community stability. During a study of the Moscow River, Kabanov (1961) found that production was depressed in waters polluted by industrial and sewage effluents. With the beginning of self purification, production and the P/R ratio increased.

SUMMARY

Gross primary productivity in Peoria Lake was apparently depressed due to a number of reasons, the most important factor appearing to be depressed efficiency. Productivity was, however, similar to that which is found in the oxygen sag zone of many polluted streams.

Production-respiration ratios were usually less than unity indicating a heterotrophic community. Production at the South Station was somewhat higher than at the North Station resulting in a P/R ratio which was nearer to unity. This would seem to indicate a more stable environment.

ACKNOWLEDGMENT

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