
Photosynthetic Productivity in a Small Pond[1]

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Oxygen is necessary for the release of energy essential for life processes, and the availability of oxygen limits the distribution and survival of organisms in a community. In an aquatic community oxygen is made available either by photosynthesis of green plants or by diffusion from the atmosphere.

A symbiotic relationship exists between bacteria, algae, and various other plankters (Bartsch and Allum, 1957). Digestive and oxidative activities of bacteria stabilize organic material and at the same time release carbon dioxide, ammonia, and other nutrients needed by algae. The newly-released substances are used by the algae, and oxygen released by algal photosynthesis tends to maintain an aerobic situation. Oxygen production by photosynthesis may be sufficient to sustain the respiration of a community, but if not, the deficiency may be overcome by diffusion. Aquatic communities tend to progress toward a steady state wherein the oxygen production within the community is sufficient to balance or exceed the uptake of oxygen by the community. These oxygen relationships can be used to classify aquatic communities (Odum, 1956).

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The oxygen relationships of a small pond, "Theta Pond", on the Oklahoma State University campus were studied during the summer of 1961. Community respiration, photosynthetic productivity (production of oxygen by photosynthesis), and diffusion were measured.

Dissolved oxygen and temperature were measured *in situ* at two-hour intervals for a 24-hour period on each sampling date. The dissolved oxygen concentration was determined colorimetrically from samples fixed by the Alsterberg modification of the Winkler method. Photosynthetic productivity, community respiration and diffusion were calculated by the construction of 24-hour rate-of-change curves as in Figure 1 (Odum and Hoskin, 1958; Copeland, 1961). The euphotic zone was estimated by measuring the depth at which light penetration was reduced to one per cent of surface illumination.

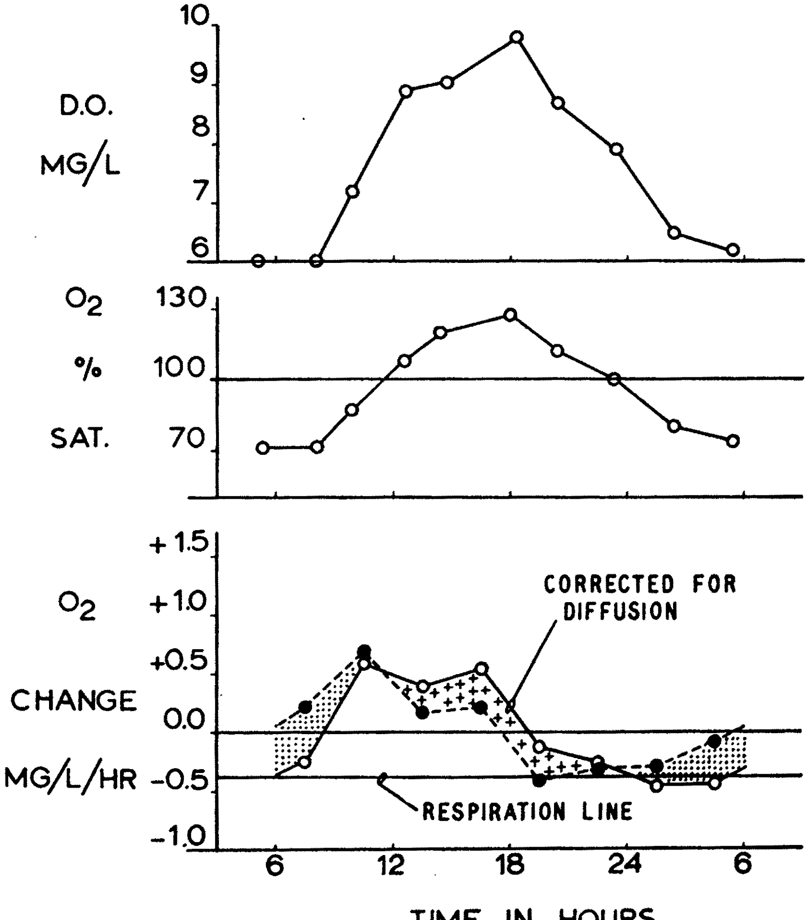

Figure 1: A representative diurnal rate-of-change curve for oxygen in Theta Pond. The area indicated by plus-marks denotes the amount of oxygen lost from the community due to diffusion; the stipled area denotes the amount gained.

OBSERVATIONS AND DISCUSSION

The total oxygen uptake of living organisms present in the water, including bacterial decomposition of organic matter suspended in the water or settled on the bottom, is attributed to community respiration. In communities with small amounts of organic matter, productivity may exceed respiration, but with large amounts of organic matter, respiration may exceed productivity. A concentration of organic matter in the water is possible at which production will balance respiration.

The productivity/respiration (P/R) ratio enables one to make a classification of communities into autotrophic and heterotrophic types (Odum, 1956). An autotrophic community is one that yields a P/R ratio greater than one (productivity exceeds respiration). A heterotrophic community is one that yields a P/R ratio of less than one (respiration exceeds productivity). Aquatic communities tend to undergo succession from the heterotrophic to the autotrophic type unless there is a renewal of organic material.

Theta Pond exhibited the autotrophic condition on only one sampling date (Table I, June 27). Prior to this date there had been two weeks without precipitation and no new organic material had been washed into the pond from the watershed. Consequently there had been sufficient time for progressive oxidation and stabilization of much of the organic material by bacteria, and the community had changed to an autotrophic state.

A relatively high P/R ratio, but still heterotrophic, was observed July 28 (Table I). Precipitation of 2.0 inches was recorded July 6 and 7, 1.55 inches was recorded July 13, 14, and 15, and 1.2 inches was recorded July 21 and 22. The six days without wash-in of organic matter had allowed the community to progress toward autotrophy.

The smallest P/R ratio observed (0.115) is presumed to be the result of an abundance of organic material in the community. The September 14 sampling date followed a precipitation of 5.05 inches on September 12 and 13. Most of the 5.05 inches fell within a few hours, washing a high load of organic material into the pond. The P/R ratio had risen to 0.219 by September 19 as the daily respiration decreased from 9.50 to 7.30 gm O_2/M^2/day (Table I). Productivity increased during the period from 1.10 to 1.60 gm O_2/M^2/day. The digestive and oxidative activities of bacteria and settling had reduced the quantity of organic matter present. This is substantiated by the reduction in turbidity indicated by the increase in depth of the euphotic zone between September 14 and 19 (from 0.15 to 0.31 M, Table I).

It would be desirable to follow the entire path of stabilization until an autotrophic condition was attained. Frequent precipitation prevented completion of the entire successional pattern.

When productivity and respiration values are considered on an areal basis as has been done above, changes in the depth of the euphotic zone may obscure the productive potential. If the values in gm O_2/M^2/day are converted to gm O_2/M^3/day (Table II), an estimation is given of the algal productivity under more nearly optimal conditions near the surface. The productivity values, which in Table I appear rather erratic, are of the same order of magnitude in Table II. The slightly higher productivity value on June 27 may have resulted from an increase in the algal population after a lengthy period of stabilization. The slightly lower productivity value on September 19 may have been caused by the turbid condition of the water. Since turbid water reduces the amount of effective sunlight for photosynthesis, the five days of increased turbidity may have reduced the algal population.

TABLE I

Community characteristics for Theta Pond during the summer of 1961.

	June 27	July 28	Sept. 14	Sept. 19
Productivity Gm O_2/M^2/day	4.97	7.32	1.10	1.60
Respiration Gm O_2/M^2/day	4.60	8.40	9.50	7.30
Euphotic zone depth in meters	0.50	1.00	0.15	0.31
Diffusion/hour Gm O_2/M^2/hour	1.70	0.37	4.00	1.50
Total diffusion Gm O_2/M^2/day	-0.37	1.08	8.40	5.70
P/R ratio	1.080	0.871	0.115	0.219

TABLE II

Photosynthetic productivity and community respiration on a volumetric basis for Theta Pond during the summer of 1961.

	June 27	July 28	Sept. 14	Sept. 19
Productivity Gm O_2/M^3/day	9.90	7.30	7.60	5.20
Respiration Gm O_2/M^3/day	9.20	8.40	63.60	23.50

Examination of the community respiration values on a volumetric basis indicates a different pattern. There is a very high respiration (63.6 gm O_2/M^3day) on September 14 which is likely the result of an influx of organic material from the watershed. This high respiration value is reduced to 23.5 gm O_2/M^3/day in only five days, presumably by bacterial activity (Table II).

A pond-series community in which the P/R ratio was less than one was reported by Copeland (1961). The ponds in that study contained organically enriched water from oil refineries and there was a constant renewal of organic matter. The ponds were designed to hold the water for periods of 37 to 60 days which allowed time for bacterial action to take place. The community had "succeeded", at the end of the pond-system, to a P/R ratio of almost one. A P/R ratio of less than one was observed by Butler (unpublished data) in a pond which was organically enriched from the watershed, while in an adjacent pond with no watershed, the P/R ratio was greater than one.

When community respiration requires more oxygen than is produced by photosynthesis, there must be a source of oxygen to satisfy this demand. That source is the diffusion of oxygen into the community from the atmosphere. The rate of diffusion and the total daily diffusion may be calculated from a diurnal rate-of-change curve for dissolved oxygen

(Figure 1). The total diffusion is obtained by substracting the amount of oxygen lost to the atmosphere when the water was supersaturated from the amount gained when the water was undersaturated. Diffusion out is represented in Figure 1 by the area under the curve indicated by +'s. Diffusion in is represented by the stipled area. In Theta Pond, when the P/R ratio was less than one, the total daily diffusion equaled the deficit of oxygen (Table I). On the one occasion when the P/R ratio was greater than one, there was a negative total diffusion, indicating a net loss to the atmosphere.

LITERATURE CITED

Bartsch, A. F. and M. O. Allum. 1957. Biological factors in treatment of raw sewage in artificial ponds. Limnol. and Oceanog. 2:77-84.

Copeland, B. J. 1961. Primary productivity in oil refinery effluent holding-ponds. M.S. Thesis, Okla. State Univ., Stillwater, Okla. 46 pp.

Odum, H. T. 1956. Primary production in flowing waters. Limnol. and Oceanog. 1:102-117.

Odum, H. T. and C. M. Hoskin. 1958. Comparative studies on metabolism of marine waters. Pub. Inst. Mar. Sci., Univ. of Texas. 5:16-46.