OXYGEN CONSUMPTION OF THE SEDIMENTS AND POPULATIONS OF *CHAOBORUS PUNCTIPENNIS* (SAY) IN ARBUCKLE LAKE, OKLAHOMA

D. Marshall Barker
Department of Entomology
and
Jerry Wilhm
Department of Zoology, Oklahoma State University, Stillwater, OK 74078

Oxygen consumption by the sediments and by *Chaoborus punctipennis* was measured in Arbuckle Lake. Sediment organic matter and oxygen consumption were greater in the central pool than in the arms. Oxygen consumption of the phantom midge ranged from 1.1 to 10.0 *μl* O_2 (mg dry wt) $^{-1}$ h^{-1}. Consumption was generally greater in organisms collected from the central pool than in those taken from the arms. The maximum value was measured on 16 December in both areas.

INTRODUCTION

Oxygen consumption of the sediments and benthic macroinvertebrates has been related to several variables in lakes. Although a linear relationship exists between the oxygen concentration of the water and the rate of the consumption by the sediments (1, 2, 3), seasonal variation of oxygen consumption has been shown to be more dependent on the temperature of the system than oxygen concentration (4, 5). Consumption by the sediments has been correlated with the concentration of organic matter (6).

Oxygen consumption of several species of benthic invertebrates has been shown to increase linearly with rising temperatures in laboratory studies (7, 8). Aquatic insects generally show an oxygen consumption that is independent of the ambient oxygen content (9). Some benthic invertebrates are able to survive prolonged exposure to anoxia (10, 11) by the use of hemoglobin and anaerobic metabolism.

The objective of the present paper was to measure the seasonal changes of oxygen consumption in the sediments and of *Chaoborus punctipennis* (Say) in Arbuckle Lake. Arbuckle Lake, located in Murray County, has a surface area of 951 ha with mean and maximum depths of 9.4 and 27.4 m, respectively. Additional information and a sketch of the lake is given in Toetz (12). The lake stratifies strongly in summer, which permits comparison of oxygen consumption under different temperature, dissolved oxygen, and conductivity levels (13). Since the concentration of the organic matter increases with depth in Arbuckle Lake (14), the relationship between the concentration of organic matter and oxygen consumption can be examined.

MATERIALS AND METHODS

Two stations were sampled at 26 m in the central pool of Arbuckle Lake and one station in each of the three arms at 15 m. Samples were collected monthly from 15 March to 16 December 1978. Temperature and dissolved oxygen were measured with a Yellow Springs Instrument (YSI) meter (Model 54A) and conductivity with a YSI conductivity meter (Model 33). Percent organic carbon was determined by an oxidation procedure (15).

An Ekman dredge was used to collect sediment samples and fourth instar larvae of *C. punctipennis.* Samples were transported in ice chests to the laboratory and their oxygen consumption measured with a Gilson respirometer at the field temperature. For analysis of oxygen consumption by the sediments, 3 g wet weight and 2 m*l* of bottom lake water were added to each 15-m*l* reaction flask. One reaction flask with 2 m*l* of lake water served as a control. Tests were run for 3 h. For analysis of oxygen consumption of *C. punctipennis*, 20 organisms and 5 m*l* of lake water were added to the flasks. Two flasks with 5 m*l* of lake water served as a control. Readings were taken every 30 min for 4 h. After measuring consumption, samples were dried for 24 h at 150° C and weighed. Values are expressed as consumption per dry weight of sediment or per dry weight of biomass. Three sediment samples and five samples of phantom midges were measured at each station monthly. Further information is given by Barker (16).

RESULTS

Since values were similar among the two stations in the central pool and among the three stations in the arms, means are given on Table 1. Temperature increased to 26ºC at 15 m in the arms, but the maximum recorded at the 26 m stations in the central pool was 17ºC. Low values of dissolved oxygen were measured on 9 June in both areas. Values exceeded 2 mg l^{-1} in the arms on 16 September and in the central pool on 22 October. Conductivity varied from 298 to 460 μmho. Values increased in summer, reaching maximum values on 15 August.

Sediment organic matter ranged from 5.1 to 6.8%. Values tended to decrease in summer in the arms, reaching the minimum on 11 July. Sediment organic matter remained high during summer in the central pool.

Oxygen consumption of the sediments ranged from 0.09 to 1.18 μl O_2 (g dry wt)$^{-1}$ h^{-1}. Consumption was significantly greater ($p = 0.05$) at the central pool stations than in the arms in summer and fall. Consumption tended to decrease at the arm stations, reaching the minimum on 16 September. In contrast, the maximum value measured in the central pool was on 11 July.

Populations of *C. punctipennis* exhibited extensive seasonal fluctuations in density in Arbuckle Lake. Density was 3442 individuals m^{-2} in the central pool on 29 April, but was less than 50 individuals m^{-2} on 9 June. Data on oxygen consumption are missing on several dates because of an insufficient number of individuals. Oxygen consumption of *C. punctipennis* ranged from 1.1 to 10.0 μl O_2 (mg dry wt)$^{-1}$ h^{-1}. Considerable fluctuation existed among and within areas. Values were greater in the central pool than in the arms on all dates except on 29 April. Seasonal variation was different in the arms and the central pool. In the arms, oxygen consumption of *C. punctipennis* was extremely high on 29 April and 16 December, while values tended to increase in the central pool, reaching the maximum on 16 December.

DISCUSSION

Sediment organic matter was greater in summer and fall at the 26 m stations in the central pool than at the 15 m stations in the arms. Clay and Wilhm (14) found that the sediment particle size was smaller in the central pool than in the arms of Arbuckle Lake. After 12 h, over 60% of the particles remained in suspension in the central pool, while 51-57% remained at the 15 m stations in the arms. An inverse relationship exists between particle size and oxygen consumption (6, 17). The quantity of organic matter was found to be related

TABLE 1. *Physicochemical condition of the water in the hypolimnion and oxygen consumption rates of the sediments and of* Chaoborus punctipennis *in Arbuckle Lake in 1978.*

Variable	Depth (m)	15 Mar	29 Apr	9 Jun	11 Jul	15 Aug	16 Sep	22 Oct	24 Nov	16 Dec
Temperature	15	5	17	19	24	26	26	20	14	8
(C)	26	5	11	14	16	17	17	17	14	8
Oxygen	15	8.8	5.4	1.0	0.1	0.1	2.3	4.9	—	8.4
(mg l^{-1})	26	8.6	4.7	0.3	0.1	0.1	0.2	2.4	—	7.7
Conductivity	15	310	417	385	423	460	457	425	352	298
(μmho)	26	315	390	410	422	455	410	422	348	305
Sediment OM	15	6.7	4.7	5.2	5.1	5.3	5.8	5.9	5.9	5.2
(%)	26	6.8	5.8	6.0	6.4	6.8	6.2	6.7	6.3	6.3
Sediment OC*	15	.49	.39	.39	.32	.27	.09	.47	.54	.64
	26	.44	.69	.69	1.18	.93	.78	.81	.82	.76
C. punctipennis OC**	15	1.1	—	8.2	5.7	2.0	1.8	4.3	—	9.1
	26	2.6	—	1.2	—	6.8	5.9	6.3	—	10.0

**μl O_2 (mg dry wt)$^{-1}$ h^{-1}

to the clay particle size of sediments and independent of depth, rate of sedimentation, and degree of eutrophication in the Great Lakes (18). The higher concentration of organic matter in the central pool of Arbuckle Lake than in the arms is probably due to the variation in particle size of the sediments among areas.

Sediment oxygen consumption was also greater at 26 m than at 15 m. A direct relationship was observed between organic matter of the sediments and density of bacteria, which would result in higher consumption rates (19). In Arbuckle Lake it is likely that higher consumption rates in the central pool were influenced by greater concentrations of organic matter and bacterial populations.

Few values of oxygen consumption rates of *C. punctipennis* are available for comparison. The range in Ham's Lake, Oklahoma, was 1.4 to 6.4 μl O_2 (mg dry wt)$^{-1}$ h^{-1} (16), which is lower than the range measured in the present study.

Oxygen consumption rates of *C. punctipennis* were greater in the central pool in late summer and fall under conditions of higher temperatures and low dissolved oxygen concentration than in spring. Oxygen consumption of several species of macroinvertebrates has been shown to increase with temperature (7, 8) and decreasing oxygen concentrations (20). However, the maximum value was measured on 16 December when temperature was low and dissolved oxygen high. No trend was observed in values in the arm. Thus, oxygen consumption of *C. punctipennis* did not appear to be related to the temperature or the concentration of dissolved oxygen.

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