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## RECORD LOW DISSOLVED OXYGEN IN THE ISLAND AREA OF LAKE ERIE<sup>1, 2</sup>

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### ABSTRACT

The first recorded severe oxygen depletion over an extensive area in the western basin of Lake Erie occurred in 1953. Because sampling in the past was done at irregular intervals, it has been difficult to determine the severity, or duration of these low-oxygen conditions. In order to get more reliable data, a program of daily sampling was initiated. From 22 June to 31 August 1966, data were collected daily at a single station south of Rattlesnake Island. Dissolved oxygen near the bottom fluctuated greatly during this time, reaching a low of 0.1 ppm on 1 July, the lowest value ever recorded from this area, and a high of 9.2 ppm on 19 July. Following this, two more periods of low dissolved oxygen occurred, the first of 3.7 ppm on 7 August and the other of 3.0 ppm on 30 August. In each of these cases, the low-oxygen condition was accompanied by an average wind speed of about six knots and an air temperature of about 26°C. In each case the drop in oxygen near the bottom was very rapid. The mean dissolved oxygen near the bottom for the summer was 5.0 ppm (61.6 percent saturation). Statistical analysis indicates a significant relationship between wind speed and dissolved oxygen.

### INTRODUCTION

In recent years much concern has been expressed about the changes that have occurred in Lake Erie. Documentary evidence indicates that subtle changes have been going on in the chemical, physical, and biological factors as far back as records are available. However, changes became so pronounced by the mid 1950's that further scientific studies were initiated.

Although the total dissolved solids in Lake Erie increased about 25 percent (Beeton, 1965) and the amounts of plant nutrients, such as nitrogen and phosphorus,

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<sup>1</sup>The authors wish to thank Dr. L. S. Putnam, Director of The Franz Theodore Stone Laboratory, Put-in-Bay, Ohio, for providing the laboratory space and equipment necessary for this project.

<sup>2</sup>Manuscript received August 26, 1967.

showed a great increase between 1900 and 1960 (Beeton, 1961; Verduin, 1964), it was the rather sudden development of low dissolved oxygen conditions near the bottom in the 1950's (Britt, 1955; Carr, Applegate, and Keller, 1965) that focused attention on the rapid changes occurring in western Lake Erie. More recently, the report of oxygen depletion near the bottom in large areas of the central basin (Beeton, 1961; 1963) indicates that the problem of eutrophication may not be confined to the western basin, but may now involve the central basin and possibly the entire lake.

The present study was undertaken to show the daily variation in dissolved oxygen and water temperatures at a single station in the western basin throughout the summer of 1966. In earlier studies, except for Chandler (1940) and Wright (1955), sampling was often infrequent and erratic. Because it is now known that pronounced changes can occur in the dissolved oxygen in the bottom waters within a few days (Carr *et al.*, 1965), sampling at frequent and regular intervals is necessary in order to detect these changes.

#### METHODS

Our station was located one half mile south of Rattlesnake Island and two miles northwest of South Bass Island (82° 50' 50" west longitude; 41° 41' 30" north latitude). The depth of the water was about 11 meters and the bottom in this area was mud-silt. This particular station was selected because it is representative of the changes occurring in the western basin as documented by Britt (1955) and Britt and Addis (unpublished report, 1966).

A buoy was used to mark the station for the duration of the study. Duplicate water samples for both temperature and dissolved oxygen (DO) were collected from both the surface and near the bottom by means of a three-liter Kemmerer water sampler. The bottom water samples were taken as close to the substrate as possible without disturbing the sediment. The sampler was lowered until it just touched the bottom and the position of the water line on the sampler cable was noted. The sampler was then lifted from this position and, after being moved to another position two to three meters distant, again lowered until the water line on the cable was within 10 to 15 cm of the water surface. The dissolved oxygen was determined by the Alsterberg modification of the Winkler Method (A.P.H.A., 1965). The samples were usually collected during the early afternoon of each day.

Air temperature and wind speeds were obtained from the Marblehead Coast Guard Station, which is located about 12 miles southeast of the collection site. These data were recorded four times daily, beginning at 12:30 A.M.

#### RESULTS

Results of the study are shown in figure 1. On 22 June the DO at the bottom was 4.6 ppm, which was lower than the minimum reported by Chandler (1940). Thermal stratification existed between 26 June and 5 July, during which time the DO reached a low of 0.1 ppm on 1 July. During this period the average daily air temperature was 26.3°C and the average daily wind speed was 6.1 knots. Dissolved oxygen remained below 1 ppm (average percent saturation of 3.0) for eight days from 28 June through 5 July. The difference in water temperature between the surface and the bottom steadily increased, reaching the maximum of 9°C on 3 July. On 6 July the wind speed increased and the DO at the bottom began to rise, reaching a peak of 9.2 ppm (110 percent saturation) on 19 July, the highest recorded at the bottom during the summer. On this day the temperature difference between the surface and the bottom was 0.5°C. During another calm period, 21-28 July, the DO in the bottom water decreased to 3.7 ppm. By 11 August, the DO was 6.6 ppm from surface to bottom. The remainder of August consisted of variations, as shown in Figure 1, until 25 August, when calm

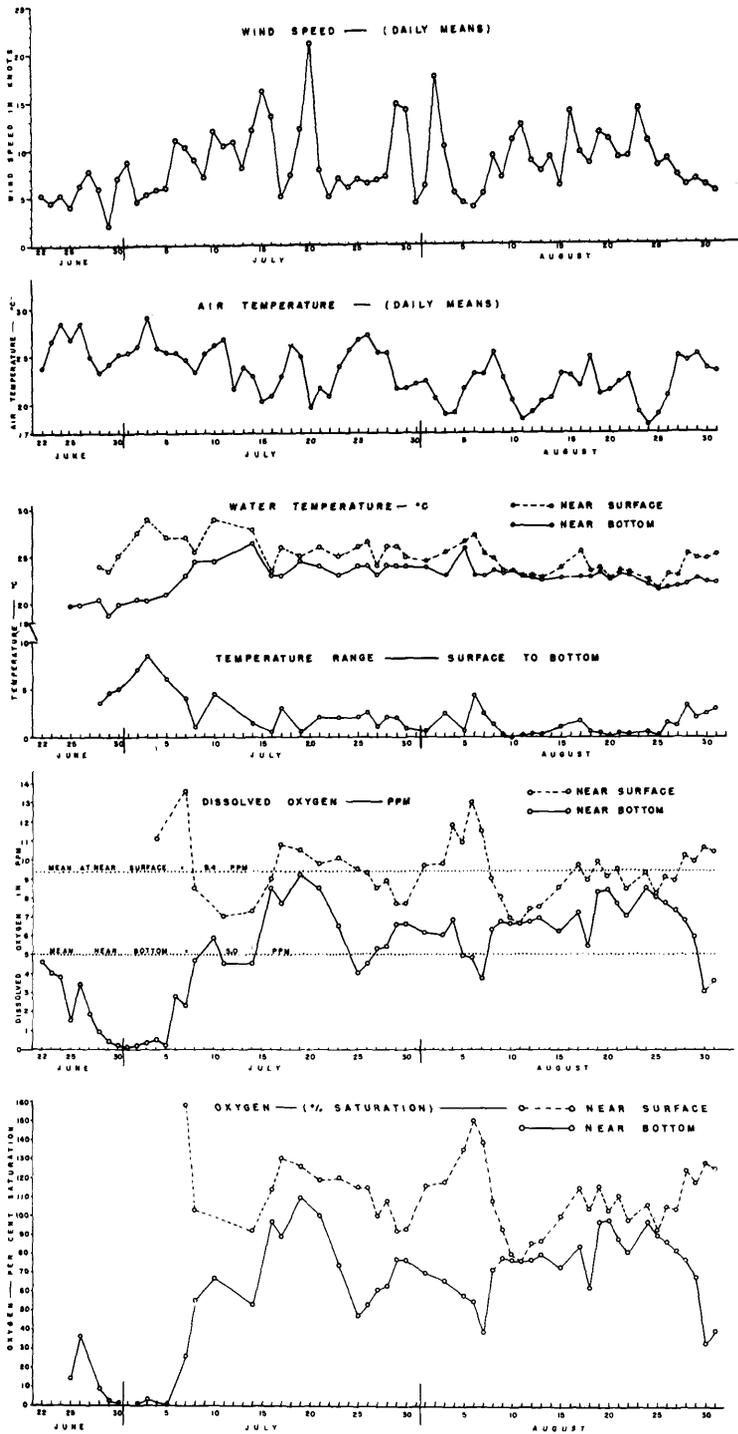


FIGURE 1.

Physical-chemical data for the period 22 June to 31 August 1966 for a single station south of Rattlesnake Island in western Lake Erie.

weather again set in and the DO in the bottom water again decreased, reaching a value of 3.0 ppm on 30 August. Wind speed during this time was around 6.3 knots daily. Unfortunately, it was necessary to suspend sampling after 31 August; however, because of increased winds, it is doubtful that the DO went below 3 ppm. Mean DO for the summer in the bottom waters was 5.0 ppm, with a mean of 61.6 percent saturation. This is based on a mean water temperature of 22.8°C at the bottom. Because of the oxygen demand of the sediment, it is probable that the DO at the mud-water interface was lower than the observed values (Carr, 1962; Carr *et al.*, 1965).

#### DISCUSSION

Wright (1955) reported that, in 1929, the average DO in the bottom water was 7.4 ppm, an average of 80 percent saturation. In 1930, at this Station 158, which was located near our collecting station, he reported that the DO near the bottom was never below 7.2 ppm. In this same report, in summarizing the data for the years 1928, 1929, and 1930, he stated that the percent saturation of the bottom waters rarely fell below 62 percent in the western basin.

Britt (1955) reported 0.7 ppm DO near the bottom on 4 September 1953, in the area covered by the present study. This was the first record of very low DO in this part of the western basin. It was associated with a great reduction in the Mayfly (*Hexagenia*) population in the mud bottom of the deep water of this area. Prior to this, Chandler studied the area during the years 1938-1948. The lowest DO that he reported, during his ten years of study, was 4.94 ppm near the bottom on 7 September 1938 (Chandler, 1940). Wright (1955) reported a low DO of 0.78 ppm on 9 August 1930 at a station (Station 59A) on the western edge of the central basin about 12 miles southeast of the present study area. At his station 158, which is in the area covered by this report, the lowest DO for 1929 and 1930 was 7.2 ppm on 1 August 1930.

Beeton (1961) reported that, in 1958, the average percent saturation at the bottom in the western basin was 80 and that it dropped only during thermal stratification. From this study he concluded that, between 1928 and 1958, little significant change had occurred in the levels of DO in the lake.

There is a significant difference between the results of the present study and the results obtained by Wright (1955), Chandler (1940), and Beeton (1961). On 22 June, the first day of this study, we found only 4.6 ppm DO, which was already below the minimums reported by Chandler (1940) and by Wright (1955) for this area. Three days later the DO was down to 1.5 ppm; then it rose to 3.0 ppm on 26 June. Only three days were required in which to reduce the oxygen from 3.0 ppm to the minimum level found by Britt in this area in 1953 and by Wright in 1930 at his southeast station (Station 59A). Within five days, from 26 June to 1 July, the DO dropped from 3.0 ppm to 0.1 ppm, the lowest value ever reported from this area.

Carr *et al.* (1965) reported the occurrence of low DO in the western basin in 1963. The lowest DO at that time was 2.6 ppm (30 percent saturation) at about 1.4 meters above the bottom on 28 June. By interpolation they concluded that, at this particular station, the DO at the mud-water interface was about 1.0 ppm. Their 23 June samples taken near the above station gave a value of 8.9 ppm DO within 0.6 meters of the bottom. Six days later, on 29 June, a sample from another station in the same area gave a value of 2.0 ppm.

By studying the weather records for the western basin, they found that the hot calm weather which had caused the thermal stratification of 28-29 June had lasted until 2 July, so they assumed that the DO had continued to drop during this period and had probably approached zero ppm. They attempted to delineate the climatic conditions which could cause thermal stratification in the western basin. Their resulting concept of these conditions can be summarized as (1) an

average daily wind speed of no more than 6 to 13 knots and (2) an average daily temperature of more than 18°C for a period of more than 5 days. They concluded that, on the basis of this summary, stratification could have occurred 33 times between 1953 and 1963.

Our data during June and July agree with the above-mentioned five-day requirement for oxygen depletion. However, though these conditions occurred in August, severe depletion of DO did not occur. Statistical analysis of our data indicated a direct relationship between wind velocity and DO concentration near the bottom. Correlation coefficients were computed relating the mean daily wind velocities to the DO at the bottom. The effects of wind velocities on the same day, one day previous, and two days previous to the time of DO determination were evaluated in this way. The three coefficients were 0.469, 0.512, and 0.530 respectively.

Other factors, such as a possible back flow of cold, oxygen-depleted water from the central basin along the bottom, may also influence the severity of DO depletion during periods of thermal stratification (Hartley, Herdendorf, and Keller, 1966).

This study further shows that the DO in the bottom water is depleted more rapidly at present than in the past. This is especially true during early summer warming periods and may be a result of increased oxygen demand by the bottom sediment (Carr *et al.*, 1965). These data and previous observations (unpublished) by us indicate that conditions may be favorable for stratification and depletion of DO at the bottom each year during June and July. This agrees with the data of Carr *et al.* (1965), in which they stated that conditions favorable to stratification and DO depletion in western Lake Erie occurred 33 times during the period 1953 to 1963, and that favorable conditions occurred at least once during each of the 11 years. It is possible that similar or even more severe DO depletion will occur in future years.

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