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study can be considered as typical hard-water lakes. The differences found are not considered of great biological significance.

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Factors Affecting Winter Fish Kills in the Coralville Reservoir, Iowa

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Abstract: The Coralville Reservoir, located on the Iowa River just upstream from Iowa City, has as its primary purpose the control of floods on the rivers downstream. A conservation pool is maintained for recreational purposes. During December 1964 and January 1965, a combination of rather unusual circumstances caused an almost complete depletion of oxygen in the reservoir and resulted in a fish kill. Oxygen demand of the incoming water from a sudden winter rain greatly exceeded the available oxygen dissolved in the lake. A heavy ice cover prevented the renewal of oxygen by wind action. The depletion continued until warm rains, melting snow, warmer weather, and the partial drainage of the lake to provide for the flood storage level resulted in the complete replacement of the contents.

INTRODUCTION

The Coralville Flood Control Reservoir is located on the Iowa River several miles upstream from Iowa City, Iowa. Authorized by an act of Congress in 1938, it was placed in operation by the Corps of Engineers, Rock Island District, in 1958.

Details of the Reservoir and Contributing Area. The reservoir is of irregular shape, filling the valley and tributaries of the Iowa River above the dam. At spillway elevation, a condition that will occur only during the most extreme flood, it has a length of 35 miles, an area of 24,800 acres, and a storage of 475,000 acre feet. The contributing area above the reservoir is 3084 square

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miles. This is mostly a rich farming area, rather flat at the upper end and becoming a gently rolling terrain in its lower portion. In spite of a considerable practice of good soil conservation, the runoff from heavy rainfall carries a great amount of sediment.

Because of large animal population and the intensive use of both natural and commercial fertilizers, the reservoir is usually well supplied with the nutrients required for the support of a high plankton population.

The Coralville Reservoir Project. On October 1, 1964, the Department of Civil Engineering, University of Iowa, began the collection of biological and chemical data on the Coralville Reservoir. The financial support for this program was provided by the Corps of Engineers, Rock Island District. Several State of Iowa Departments also cooperated by furnishing services and equipment for the project.

Water samples were collected on a weekly basis at the surface, mid-depth and bottom at two points in the impoundment, one upstream from the tributary Lake Mac Bride (Station one), the other downstream from this contributing area (Station two). Weekly samples were also taken from the Iowa River both upstream from the Coralville Reservoir and at a point downstream.

Chemical analyses, most probable number of coliform bacteria determinations and plankton counts were conducted on all samples.

Reservoir Conditions in Fall and Early Winter

Operational and Weather Conditions. At the beginning of the project in October, 1964, the reservoir was at the high conservation level of 683 feet m.s.l. and this level was held until December 15 when a gradual reduction to an elevation of 680 feet m.s.l., storage approximately 53,750 acre feet, was started. Inflow from the Iowa River had been about average for the preceding year but no large discharge peaks were experienced. Only medium or low inflows were present in July, August, and September; hence the enrichment provided by sudden runoff was absent during this period.

Chemical and Biological Conditions. During the period October 1 to December 29, the dissolved oxygen in the lake and the incoming river water was generally within the range of 70 to 100% saturation with occasional readings in excess of saturation near the lake surface. Alkalinity was fairly constant and averaged about 250 p.p.m.; the pH was usually above eight. Orthophosphate declined during the period and was nearly depleted in the reservoir by the end of December. This is probably the natural result of a very small inflow and the consumptive use of this element by the large biological population present.

The 5-day, 20°C biochemical oxygen demand of the incoming water and of the lake contents was low during the period, with a value usually less than 5 p.p.m., and at all times lower than the dissolved oxygen value. Temperatures declined gradually with the changing of the seasons and by December 29 there was evidence of a temporary stratification with a bottom temperature of 3°C and a top temperature of 1°C.

Inflowing biological population was high during the period October-December with values greater than 10,000 cells per milliliter most of the time. A peak value of 91,900 cells per milliliter, largely *Cyclotella* and *Chlorella,* was observed on October 21. Evidence of movement of this high peak value was shown by the high average value of 17,900 cells per milliliter at the upstream lake sampling station on October 28 and of 18,500 cells per milliliter on November 4 at the downstream station. This surge of biological life appeared as a peak of 15,500 cells per milliliter at the sampling point below the dam on November 10.

Combination of Events That Contributed to Fish Kill

General Conditions in the Reservoir. By the last week in December, a heavy ice cover had developed over the entire reservoir. The lake level had been reduced from the high conservation level of 683 feet msl (median sea level) to the standard level of 680 feet msl. Dissolved oxygen concentrations in the lake were adequate to support aquatic life. The average value at Station one was 13.2 ppm; at Station two, 7.6 ppm. Orthophosphate levels had fallen to an average of 0.12 p.p.m. at Station one and 0.02 ppm at Station two. The BOD (biological oxygen demand) values were 6.6 ppm and 5.9 ppm. respectively. Algal populations were still fairly high with an average of 9270 cells per milliliter at Station one and 6400 cells per milliliter at Station two.

Effect of Rainfall of December 30-*January* 1. Rainfall that occurred during the last part of December and early January contributed a rather heavy runoff into the reservoir from streams that discharge into the Iowa River, from the north side upstream from Highway 218, near Cou Falls. Although the rainfall was not extreme, the frozen condition of the soil caused a greater than normal amount of immedate runoff. Several of the small creeks entering the river above the impoundment were above bank-full stages. The Iowa River from Marengo to the reservoir was at moderately high stage and broke up its ice cover for a considerable distance in the vicinity of the Amana Colonies.

The sudden surge of runoff resulted in the introduction of plant material, livestock wastes and other organic matter washed from the frozen ground, into the reservoir. The extent of this pollution is evidenced by the high BOD values shown for the river and reservoir stations. Samples taken from the Iowa River above the reservoir had a 5-day BOD of 24.9+ ppm and 12.7 ppm on January 5 and January 12 respectively, with a dissolved oxygen concentration of 5.5 and 4.7 ppm. Reservoir Station number one had a 5-day B.O.D. value at the surface of 8.0+ ppm on January 6 and 22.2 ppm on January 12 with a dissolved oxygen level of 9.2 and 0.0 ppm respectively. The excess of BOD over the available oxygen caused depletion of dissolved oxygen beginning in the upper part of the impoundment and progressing through the reservoir. By January 19 the dissolved oxygen level at the top at Station number two, 1.5 miles upstream from the dam, had dropped to 0.5 ppm; at mid-depth it was 3.4 ppm, and at the bottom, 7.2 ppm. By February 2 the dissolved oxygen level at Lake Station one was reduced to 0.5 ppm and at Lake Station two it was 0.3 ppm.

Orthophosphate content of the inflowing water rose from 0.88 ppm on December 28 to 5.72 ppm on January 5. This inflowing water at a temperature of 1°C initially was observed as a stratified flow over the heavier water of 3°C in the upper reaches of the reservoir. On January 6 the orthophosphate content of the top part of the reservoir at Station one was 2.80 ppm while that at the bottom was a low 0.66 ppm. On January 19 a similar condition was noted in the lower part of the lake at a point 1.5 miles upstream from the Coralville Dam, where the orthophosphate content was 4.50 ppm at the top and 1.02 at the bottom. By February 2 a reasonably complete mixing had taken place. The depletion of oxygen was apparently responsible for the death of some fish within the impoundment and the movement of others into tributaries where dissolved oxygen concentrations were higher. The authors made no attempt to assess the extent of damage to the fishery.

Conditions that Brought Critical Period to End

Warm rainfall and higher temperatures on February 7 brought a considerable amount of water into the lake and raised the water surface level several feet. This necessitated a fairly heavy discharge from the reservoir. In addition, the usual reduction to the lower flood level of 670 feet by February 15 was started. These conditions, along with other precipitation and melting of snow cover, were equivalent to a complete change of the reservoir contents several times during the period February 7 to April 8. Although the 5-day 20°C BOD remained considerably in excess of the dissolved oxygen values during this period, the low water temperatures, never in excess of 3°C, and the rapid changing of the contents of the impoundment did not allow oxygen depletion. Dissolved oxygen concentrations averaged about 3 ppm on February 15 and by March 23 had risen to values of about 6 ppm at the sampling points.

Summary and Conclusions

Depletion of oxygen that resulted in a fish kill was the result of several factors. The heavy and complete ice cover that formed over the entire lake during December was an effective barrier to reaeration by wind action. The very heavy and sudden runoff from the frozen drainage areas of creeks locally entering the reservoir, or the Iowa River immediately above the reservoir, introduced a heavy load of plant matter and other agricultural pollution into the ice-covered reservoir. This pollutional load was probably unusually great because of the lack of high runoff from the areas concerned for several months prior to the December rains. The Iowa River at the Amanas was high enough to break up its ice cover (about bankful) and this also brought a surge of pollution from sanitary, industrial and agricultural wastes that had settled in the river channel during low stages or had been emptied into the river at points above. It is unfortunate that these pollutants entered the reservoir just after the reduction of the contents to normal pool level from the 683 feet msl higher autumn level. This materially reduced the water available for dilution.

The heavy ice cover also was effective in inhibiting the replacement of oxygen by the photosynthetic action of the algal population as it allowed for only a limited light penetration.

It seems rather unlikely that a complete duplication of these unfavorable conditions will occur at frequent intervals.