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THE EFFECT OF RAISING THE WATER LEVEL ON THE PRODUCTIVITY OF A MARL LAKE

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Introduction

This study is an attempt to determine the effects of an increase in water level upon the productivity of a marl lake. Marl lakes are common in southern Michigan and tend to produce few fish or other organisms. Precipitation of calcium carbonate leads to the development of bottom soils which contain much calcium and little organic matter. The effects of change in water level upon ecosystems of this type have not been studied intensively.

Roelofs (1944), Rawson (1951), Moyle (1956) and others have discussed the relationship between soil fertility and production in aquatic habitats. Kadlec (1960) and Cook and Powers (1958) found that the productivity of impoundments can be increased by manipulation of the water level. Reflooding, following the drawdown of an impoundment, was believed to result in release of nutrients from soils that had been aerated and dried during the drawdown.

It was reasoned that the flooding of about 100 acres of "new" soil would result in a release of nutrients such as occurs upon the reflooding of an impoundment after a drawdown. The aerated soils surrounding a marl lake have a higher organic content than the marl deposits of the lake basin. Decomposition of this organic material could bring about release of nutrients. The solubility of phosphorus may be increased by soil submergence (Mortimer, 1941). Under anerobic conditions, when high concentrations of carbon dioxide are present, as occurs in submerged soils, iron, calcium and magnesium go into solution as bicarbonates and phosphorus is released in a soluble form (Cook and Powers, 1958).

Study area

Big Portage Lake is in Jackson County, Michigan, T 1S, R 2E, Sec. 31 and T 2S, R 2E, Sec. 6. In February 1957, the Conservation Department installed a dam which raised the water level 3 feet. The area of the lake was increased from 335 acres to approximately 435 acres. The lake basin now has three depressions with maximum depths of 28, 34 and 43 feet. These depressions are separated by shoal areas where the water is less than 6 feet deep. Water depth is less than 5 feet in 34 per cent of the basin and less than 20 feet in 85 per cent of the basin. Beyond the 10-foot contour, there is a steep drop-off into the depressions.

In 1959 the aquatic vegetation on shoal areas consisted of *Scirpus* sp. and scattered beds of *Nymphaea odorata*. There were few weeds at depths greater than 5 feet; this is surprising since in 1946 a survey party reported that 20 species of higher aquatics were present. Of the 20 species, 10 were typically submergent forms and included *Potamogeton gramineus*, *P. pectinatus*, *P. praelongus*, *P. zosteriformis*, *Ceratophyllum demersum* and *Myriophyllum heterophyllum*. These species were reported to be common. Kadlec (1960) found that relatively minor differences in water level will cause adjustments and changes in vegetation. Thus, the elevated water level may account for the present scarcity of vegetation.

Methods

In 1953 and in the spring of 1954, water samples were collected once a month. From February 1957 through February 1960, samples were collected at irregular intervals. All collections were made at the deepest part of the lake. The depths at which water samples were collected were varied, depending on the stratification of the lake. During summer stratification three samples were taken within the epilimnion, two in the thermocline and two in the hypolimnion. At times of homothermal conditions, water samples were usually collected at 10-foot intervals.

Bottom fauna samples were collected at monthly intervals between May and October of 1953. Sampling stations were located on 2 transects at depths of 3, 15 and 25 feet. Stations 1, 2 and 3 were established in the east bay and 1A, 2A and 3A in the west bay (Fig. 1). In 1959, after the water level was raised, samples were collected each month at these same stations, where water depths were 3 feet greater than in 1953. The recently flooded lake bottom of both the east and west bays was sampled in 1959 (Fig. 1, stations 4 and 4A). In both 1953 and 1959, four bottom samples were collected each month at each station with a 6-inch Ekman dredge.

Fish were collected with trap nets in the late fall of 1953 and in the spring of 1954. Since there is virtually no growth over the winter, these fish were considered as one collection. The growth of the fish collected in 1953-54 was compared with fish collected with trap nets in the spring of 1958. The fish collected in 1958 had spent one growing season in the lake after the water level was raised.

Results

The mineral concentration of lake water is subject to large variations within a short period of time. This is especially true of phosphorus content which may vary with depth and with stratification of the lake. Figure 2 shows the phosphorus and alkalinity content from February 1953 to February 1960. The figures used on the graph represent average values for samples in the epilimnion during stratification, or average values for samples at all depths when the lake was not stratified.

In 1953 and 1954 total phosphorus ranged from a low of 6 ppb (May 1953) to a high of 25 ppb (January 1954), but it rarely exceeded 10 ppb.

In 1957 and 1958, after the water level was raised, total phosphorus ranged from a low of 23 ppb (September 1958) to a high of 41 ppb (January 1958). In 1959 and in February 1960 there was some indication of a decline in total phosphorus; such a decline was expected since the newly flooded bottom would soon release its available nutrients and begin to accumulate marl.

Total phosphorus values before and after the increase in water level were compared by means of a sign test (Dixon and Mood, 1946). Samples collected in 1953 and 1954 during spring and fall circulation, and during summer and winter stratification, were compared with samples collected during similar periods after the water level was raised. Total phosphorus content was higher after the level was raised; the difference was statistically significant at the 5 per cent level.

An increase in the soluble phosphorus after flooding was noted also; however, this difference was not significant at the 5 per cent level. With few exceptions, soluble phosphorus in the samples collected in 1953 and 1954 ranged between 1 ppb and 3 ppb; only once during these two years was there a sample with a value greater than 3 ppb. In March, May, October and December of 1953 the average amount of soluble phosphorus was less than 0.1 ppb. During 1957 and 1958, soluble phosphorus values of less than 3 ppb were recorded only twice; all other values during these years ranged between 3 ppb and 6 ppb. In February 1960 the average soluble phosphorus content was less than 2 ppb. This was the lowest value recorded since 1954.

In 1953 and 1954 the total alkalinity ranged from 132 ppm (September 1953) to 174 ppm (April 1953); most of the values exceeded 145 ppm. In 1957 and 1958 the highest total alkalinity recorded was 146 ppm; the majority of the samples ranged between 130 ppm and 140 ppm. The lowest alkalinity recorded (110 ppm) was in February 1957 immediately after the dam was installed. Although total alkalinity appeared to decrease after the water level was raised, the sign test failed to show that the difference was statistically significant.

Ball and Tanner (1951) noted a decrease in alkalinity when phosphorus was added to unproductive trout lakes. This inverse relationship between phosphorus and alkalinity was also observed here. However, the increase in phosphorus and the decrease in alkalinity were conspicuous for only 2 or 3 years. By 1959 and February of 1960 there was an indication that the bicarbonate content was again approaching the level present in 1953 and 1954. The February 1960 value of 173 ppm was almost equal to the highest value recorded in 1953.

Bottom fauna

The standing crop of bottom fauna was lower in 1959 than in 1953. In 1953 the average standing crop ranged between 25 and 45 organisms per 1/4 square foot at all stations, except station 1 in the east bay (Fig. 3). Here there were fewer than 5 organisms per 1/4 square foot. In 1959 the average standing crop did not exceed 10 organisms per 1/4 square foot at any station; at station 1 the crop of bottom fauna showed a modest increase over 1953 but did not exceed 10 organisms per 1/4 square foot. Samples taken in 1959 from stations in "new" lake bottom (4 and 4A) contained very few organisms. They were poorer than samples taken from "old" bottom in the same general areas in 1953. For comparison, samples collected before and after the raise in water level were paired by months. A sign test indicated that the difference was significant at the 1 per cent level.

Qualitatively, samples collected in 1953 were not greatly different from those collected in 1959. In 1953 the samples contained caddisfly larvae (Polycentropus), the phantom midge, Chaoborus, and 7 species of midge larvae (Chironomidae). The midges identified were: Procladius sp., Clinotanypus sp., Pseudochironomus sp., Calopsectra sp., Cryptochironomus sp., Tendipes tendipes decorus, and T. tendipes tentans. The samples collected in 1959 contained the same species except for Polycentropus (they were not abundant in 1953) and the midge Pseudochironomus.

In both 1953 and 1959 Chaoborus and chironomids comprised nearly 100 per cent of the population at the deep-water stations. The major difference between the samples was the great reduction in the number of Chaoborus in 1959. Chaoborus made up 87 per cent of the population in 1953 and 11 per cent in 1959. Except in the shallow-water samples from the east bay there was no marked reduction of chironomids in 1959. Hence it seems that the contribution to the food chain by the midges did not change appreciably.

Fish

Wide variations in the growth rate of fish may result from changes such as increased food supplies or decreased competition for food. At Big Portage Lake it was assumed that any increase in productivity resulting from the raised water level would be reflected in the growth rate of the fish. The acceleration (if any) in growth would be most pronounced in the growing season of 1957.

Bluegills (Lepomis macrochirus), black crappies (Pomoxis nigromaculatus), and largemouth bass (Micropterus salmoides) had a greater average total length after the water level was raised (Fig. 4). The average length of bluegills of each age group collected in 1958 was about 1 inch greater than that of fish of the same age collected in 1953-54; average lengths of 2- and 3-year-old black crappies collected in 1958 exceeded by almost 3 inches the average lengths of fish of the same ages collected in 1953-54, and for other age groups the improvement amounted to about 1 inch; all age groups of largemouth bass showed an increase of about 1 inch in 1958 over 1953-54.

To assess the effect of the raised water level, the amounts of growth made by fish during 1953 and 1957 were compared. Bluegills and largemouth bass which had completed their fourth growing season and black crappies which had completed their second growing season during these two years were selected for this comparison because these age groups were represented in sufficient quantity to permit reliable statistical comparison. The average growth increment of bluegills in their fourth growing season was 1.4 inches (growth during 1953) for those collected in 1953-54 and 2.4 inches (growth during 1957) for those collected in 1958. The individual growth increments during the fourth growing season were more variable for bluegills collected in 1958 than for those collected in 1953-54. For 1958, increments ranged from 0.3 inch to 3.7 inches (standard deviation 1.18); for 1953-54, the increments ranged from 0.7 inch to 2.8 inches (standard deviation 0.35). Because the variances of the increments were unequal, the Welch procedure (Brownlee, 1960) was used to test whether the difference in increments, between 1953 and 1957, was statistically significant. The test showed the difference to be significant at the 0.01 probability level. The greater variation in growth after the water level was raised indicates that all bluegills did not respond equally. The larger fourth-year growth increment of the bluegills collected in 1958 accounted for their greater total length; there was not a significant difference in length between the two groups at the end of the third growing season.

The growth increment of black crappies in their second growing season was 2.9 inches in 1953 and 6.2 inches in 1957. This difference was significant at the 0.01 probability level. There was no significant difference between the first year growth of black crappies in the two collections; therefore the greater total length in 1958 was due only to greater growth during 1957.

The average growth increment of largemouth bass in their fourth growing season was 2.5 inches in 1953 and 3.0 inches in 1957. The bass taken in 1958, however, had been growing more rapidly during each year of life than those collected in 1953-54. The change in water level therefore did not account for the total increase in the length of largemouth bass collected in 1958 over those taken in 1953-54.

Discussion

There is evidence that the elevation of the water level of Big Portage Lake resulted in changes in the level of nutrients and therefore may have increased basic productivity. A higher phosphorus and lower alkalinity content of the water persisted for two years after the change in water level. During the third season these elements returned nearly to their former concentrations.

The bottom fauna did not respond to the increased phosphorus content of the water. There was a significant decrease in the average standing crop of benthos at the stations sampled between 1953 and 1959. It is possible that this decrease in bottom fauna took place between 1953 and the time the water level was raised (1957). It is also possible that the poor crop of benthos in 1959 was independent of the change in water level. Chaoborus exhibited the greatest decrease in numbers; however, there was little change in the number of chironomid larvae. Consequently the contribution of the bottom fauna to the food chain may not have changed appreciably. Chironomids and Chaoborus were the only abundant bottom organisms. The reduction in bottom fauna may have been related to the scarcity of aquatic weeds after the water level was raised.

Although an increase in bottom fauna did not occur, the growth rate of bluegills, largemouth bass and black crappies increased after the water level was raised. Possibly the increased growth resulted from a greater production of zooplankton. The increase in phosphorus and the reduction in higher aquatic plants may have resulted in a greater production of phytoplankton, periphyton and zooplankton.

Acknowledgments

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Literature cited

Ball, R. C., and H. A. Tanner. 1951. The biological effects of fertilizer on a warm-water lake. Mich. State College Agr. Exp. Sta., Tech. Bull. 223. 32 pp.

Brownlee, K. A. 1960. Statistical theory and methodology in science and engineering. John Wiley & Sons, Inc., New York. 569 pp.

Cook, A. H., and C. F. Powers. 1958. Early biochemical changes in the soils and waters of artificially created marshes in New York. New York Fish and Game Journal, 5(1): 9-65.

Dixon, W. J., and A. M. Mood. 1946. The statistical sign test. Jour. Am. Stat. Ass., 41: 556-566.

Kadlec, J. A. 1960. The effect of a drawdown on the ecology of a waterfowl impoundment. Mich. Dept. of Cons. Game Div., Report 2276. 181 pp.

Mortimer, C. H. 1941. The exchange of dissolved substances between mud and water in lakes. Jour. Ecol., 29: 280-329.

Moyle, J. B. 1956. Relationships between the chemistry of Minnesota surface waters and wildlife management. Jour. Wildlife Management, 20(3): 303-320.

Rawson, D. S. 1951. The total mineral content of lake water. Jour. Ecol., 32: 669-672.

Roelofs, E. W. 1944. Water soils in relation to lake productivity. Mich. St. College Agr. Exp. Sta., Tech. Bull. 190. 31 pp.

Figure 1.--Location of stations where bottom samples were collected in Big Portage Lake in 1953 and in 1959.

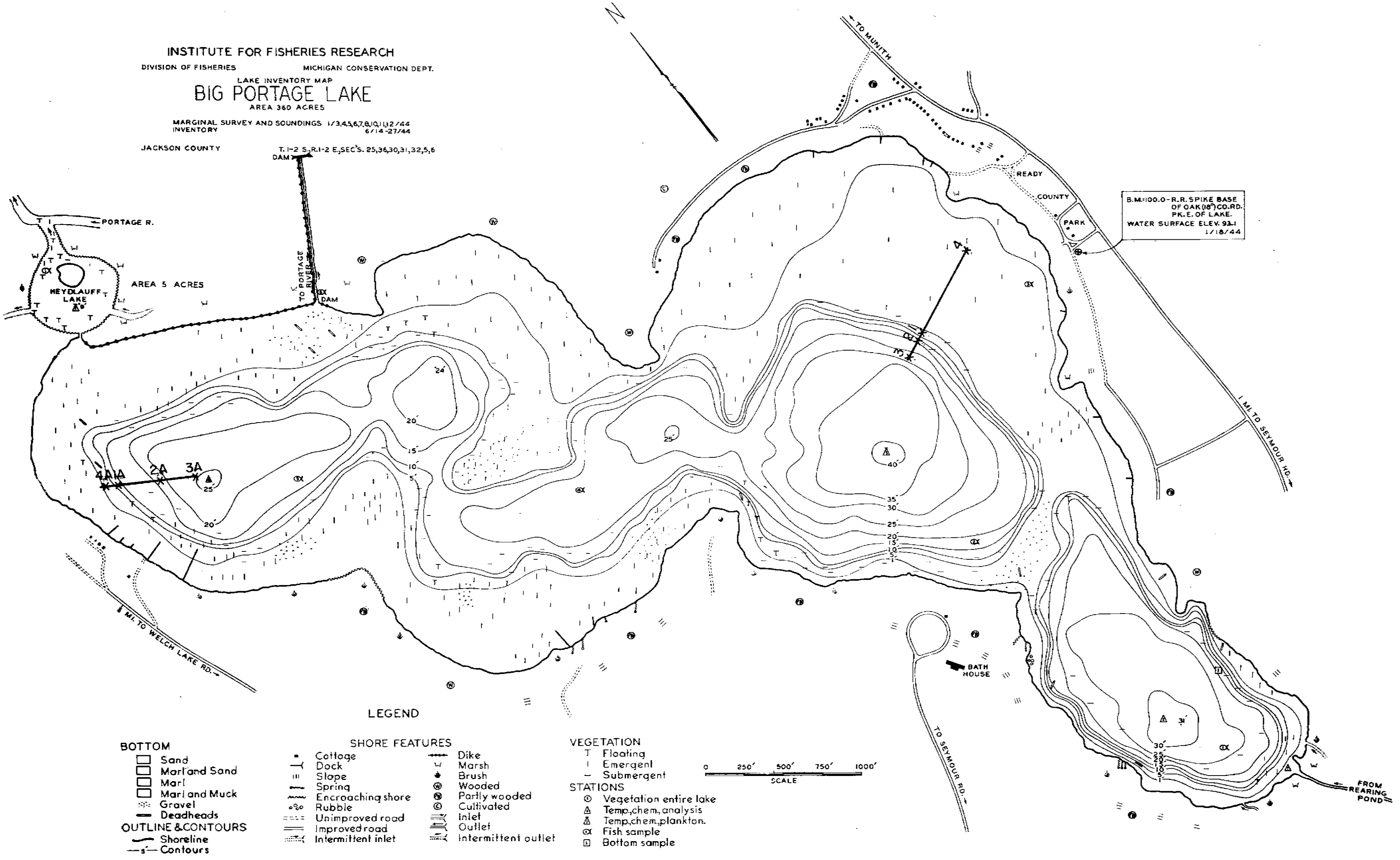
INSTITUTE FOR FISHERIES RESEARCH
DIVISION OF FISHERIES
MICHIGAN CONSERVATION DEPT.
LAKE INVENTORY MAP
BIG PORTAGE LAKE
AREA 360 ACRES
MARGINAL SURVEY AND SOUNDINGS 1/3,4,5,6,7,8,10,11,12/44
INVENTORY 6/14-27/44
JACKSON COUNTY
T. 1-2 S., R. 1-2 E., SEC'S. 25,36,30,31,32,5,6
N
DAM
DAM
TO PORTAGE RIVER
PORTAGE R.
HEYDLAUFF LAKE
AREA 5 ACRES
TO MUNITH
READY
COUNTY
PARK
B.M.=100.0-R.R. SPIKE BASE OF OAK (18") CO. RD. PK. E. OF LAKE.
WATER SURFACE ELEV. 93.1 1/18/44
1 MI. TO SEYMOUR RD.
8 MI. TO WELCH LAKE RD.
TO SEYMOUR RD.
BATH HOUSE
FROM REARING POND
1A
2A
3A
4A
4
3
2
24
20
15
10
5
25
40
35
30
31
LEGEND
BOTTOM
Sand
Marl and Sand
Marl
Marl and Muck
Gravel
Deadheads
OUTLINE & CONTOURS
Shoreline
Contours
SHORE FEATURES
Cottage
Dock
Slope
Spring
Encroaching shore
Rubble
Unimproved road
Improved road
Intermittent inlet
Dike
Marsh
Brush
Wooded
Partly wooded
Cultivated
Inlet
Outlet
Intermittent outlet
VEGETATION
T Floating
I Emergent
– Submergent
STATIONS
Vegetation entire lake
Temp., chem., analysis
Temp., chem., plankton.
Fish sample
Bottom sample
0 250' 500' 750' 1000'
SCALE

Figure 1

Figure 2.--Total phosphorus, soluble phosphorus, and total alkalinity concentrations of Big Portage Lake from February 1953 to February 1960.

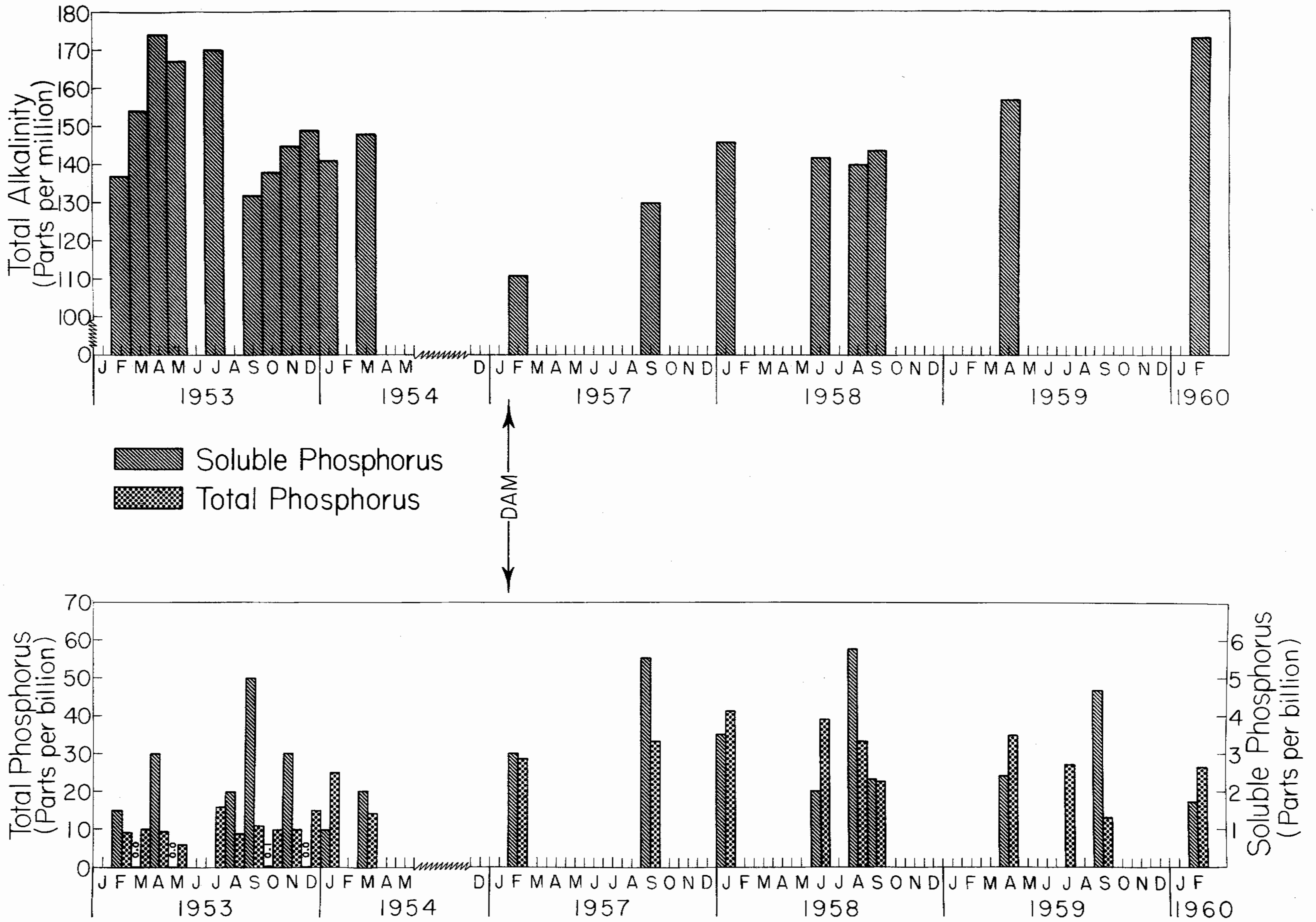
Total Alkalinity
(Parts per million)
180
170
160
150
140
130
120
110
100
0
J F M A M J J A S O N D J F M A M D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F
1953
1954
1957
1958
1959
1960
Soluble Phosphorus
Total Phosphorus
DAM
Total Phosphorus
(Parts per billion)
70
60
50
40
30
20
10
0
Soluble Phosphorus
(Parts per billion)
6
5
4
3
2
1
J F M A M J J A S O N D J F M A M D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F
1953
1954
1957
1958
1959
1960

Figure 2

Figure 3.--Average standing crop of bottom fauna per 1/4 square foot at stations sampled in Big Portage Lake in the years 1953 and 1959.

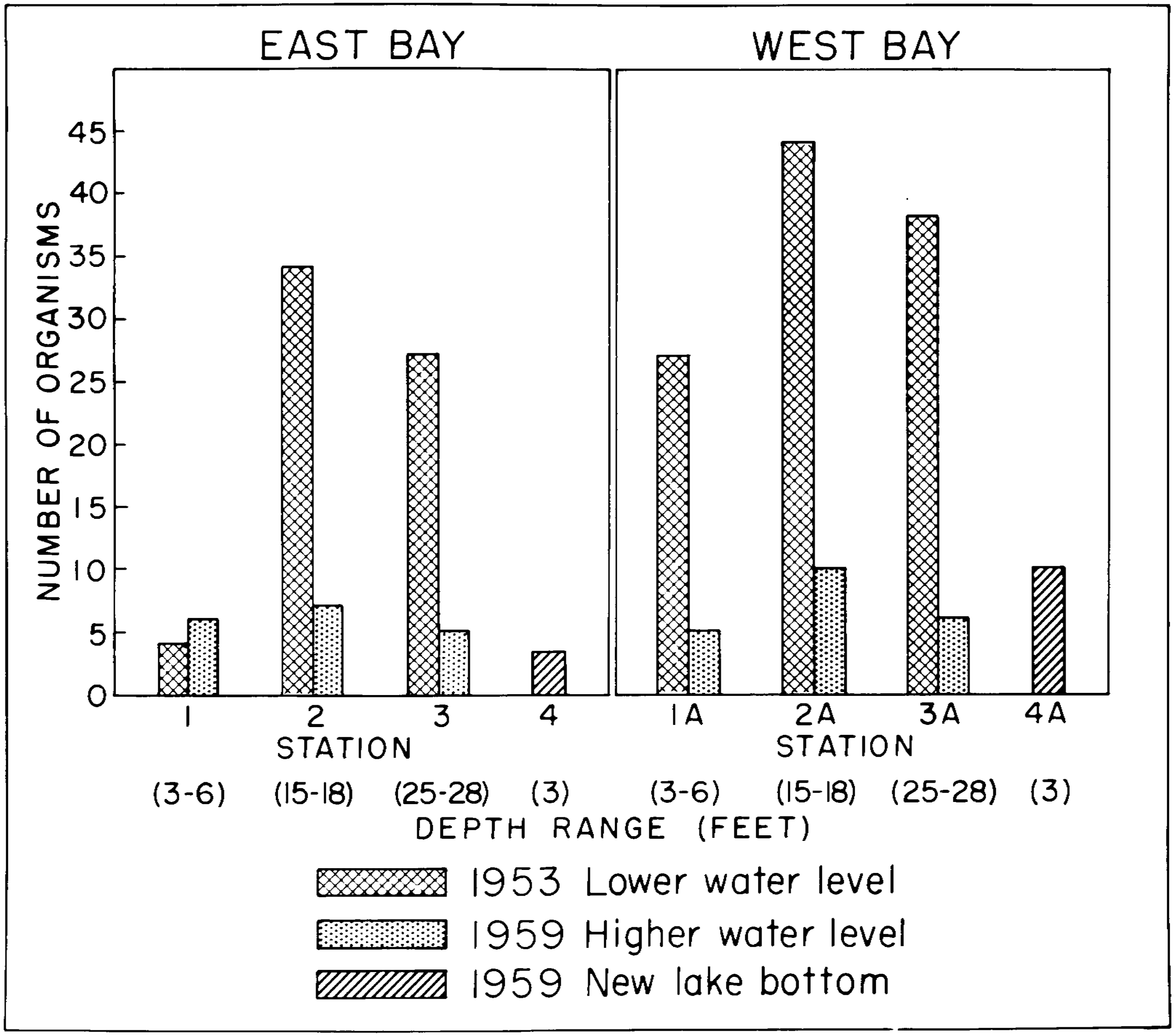
EAST BAY
WEST BAY
NUMBER OF ORGANISMS
0
5
10
15
20
25
30
35
40
45
1
2
3
4
1A
2A
3A
4A
STATION
STATION
(3-6)
(15-18)
(25-28)
(3)
(3-6)
(15-18)
(25-28)
(3)
DEPTH RANGE (FEET)
1953 Lower water level
1959 Higher water level
1959 New lake bottom

Figure 3

Figure 4.--Growth curves for fish collected from Big Portage Lake in the years 1953, 1954 and 1958.

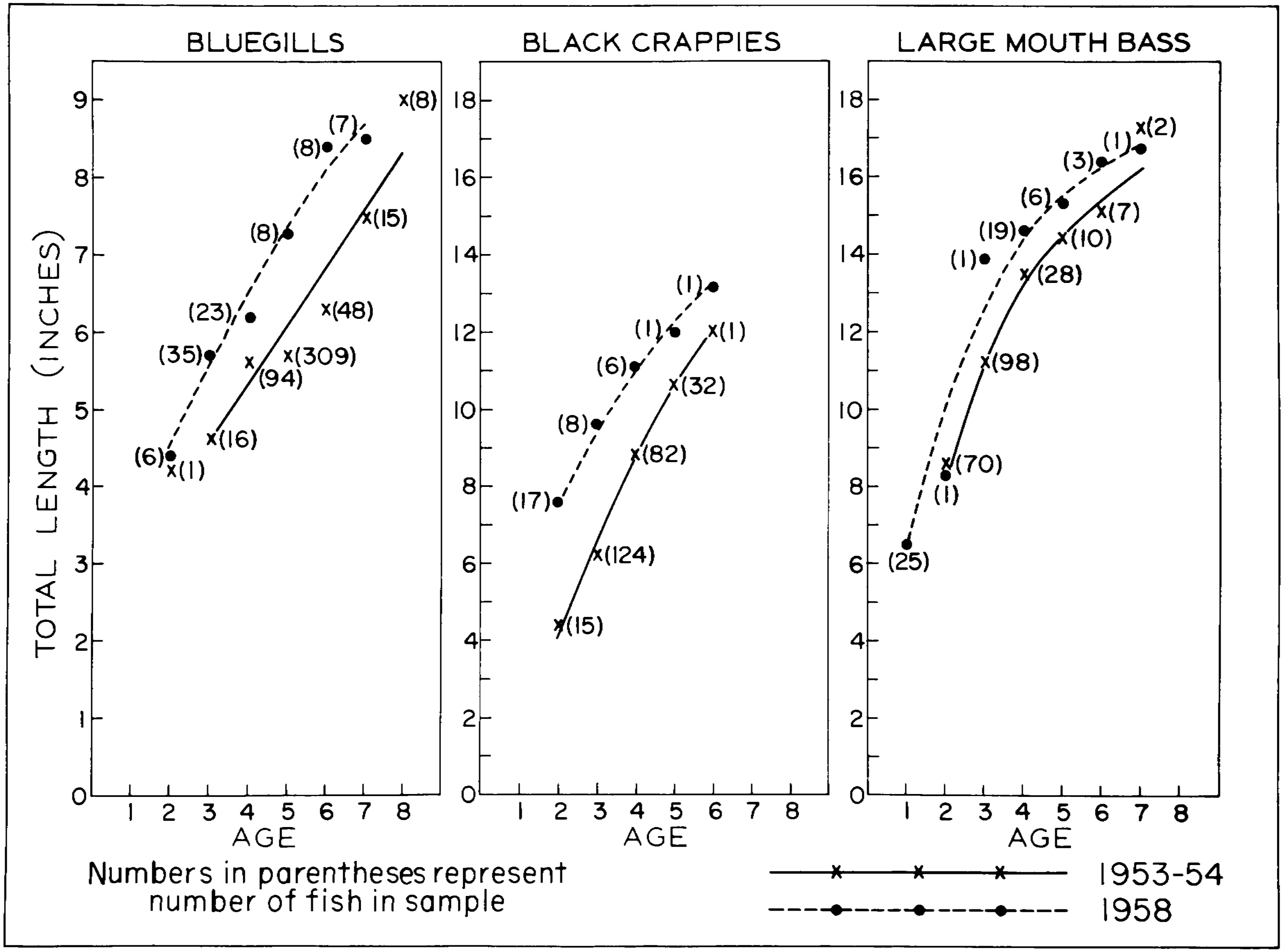
BLUEGILLS
BLACK CRAPPIES
LARGE MOUTH BASS
TOTAL LENGTH (INCHES)
0
1
2
3
4
5
6
7
8
9
(6)
x(1)
x(16)
(35)
x
(94)
(23)
x(309)
x(48)
(8)
x(15)
(8)
(7)
x(8)
2
4
6
8
10
12
14
16
18
(17)
x(15)
x(124)
(8)
x(82)
(6)
x(32)
(1)
x(1)
(1)
(25)
(1)
x(70)
x(98)
(1)
x(28)
(19)
x(10)
(6)
x(7)
(3)
(1)
x(2)
1 2 3 4 5 6 7 8
AGE
Numbers in parentheses represent number of fish in sample
1953-54
1958

Figure 4