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Fertilization of natural lakes in Michigan[1]

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Abstract

Inorganic fertilizer was applied to two state owned lakes in northern Michigan, one a 4.3 acre trout lake and the other a 27.5 acre warm-water lake. Two nearby, similar lakes were kept under observation as controls.

Fertilizer brought about a plankton algae bloom the first summer in the warm-water lake and produced a very heavy growth of filamenteous algae the second summer. The trout lake responded much less to the added nutrients and the reading of Secchi's disk was at no time less than 8.2 feet.

No appreciable oxygen depletion occurred the winter following the first season of fertilization. Chemical analysis in February

of the second winter showed severe oxygen depletion, with oxygen levels at less than 1 p.p.m. at all depths, and an almost complete winterkill occurred in both fertilized lakes. No winterkill occurred in the two lakes serving as controls.

Introduction

With organic and inorganic fertilizers of proven value as tools of fisheries management for farm ponds, it has been felt that an extension of their use to include certain of our natural waters should be made to determine whether an increase in the growth of fish would result from the added nutrients, and if such an increase did occur whether or not the expenditure of time and materials required to produce it could be justified.

With approximately 11,000 lakes in Michigan (Brown, 1943) it does not seem that fertilization of many of them, especially the warm-water lakes, could be justified under present conditions where the adequate harvesting and balancing of the fish crop are perhaps more pressing questions of management than is an increase of the standing crop of fish.

It was the opinion of Dr. A. S. Hazzard, Director of the Institute for Fisheries Research of Michigan, that the most likely field for lake fertilization in Michigan was in the relatively small trout waters of the state which are essentially of low productivity. These lakes, because they do support trout, have greater value to the angler than lakes of similar size that support warm-water species of fish.

Lakes of the northern portion of the lower peninsula of Michigan, where soil conditions permit only meager farming, are generally low in productivity of fish as compared with lakes of southern Michigan. It was believed that these lakes, having the greatest need for artificial enrichment, offered the best opportunity to adequately evaluate the effects of fertilizer on natural lakes.

Two pairs of lakes in the northern section of the lower peninsula of Michigan were selected for the fertilization experiment. One pair, North and South Twin lakes in Cheboygan County, were chosen as representatives of relatively unproductive warm-water lakes in an area where the most important industry is the resort and tourist trade. In a section having many good trout streams these lakes offer about the only pan fish waters of the immediate area and as such are of strategic importance locally. The other two lakes selected are trout waters, located about 20 miles south of the warm-water lakes in the state-owned Pigeon River Forest area. These lakes were also designated as North Twin and South Twin and had been included in an experimental management program (Eschmeyer, 1937) several years prior to the start of this project.

Description of the Warm-water Lakes

North Twin Lake (Cheboygan County).—This lake is located in the jack pine plains of the Little Sturgeon River drainage area, has a surface area of 27.5 acres, a maximum depth of 15 feet, with the clear-water zone seldom extending below a depth of 12 feet. The lake has no inlet or outlet. The bottom is pulpy peat except on the

windswept shoal zone adjoining the narrow sand beach. The surrounding land is covered with second growth pine and aspen and has no agricultural value. The lake does not stratify, having a complete circulation throughout the summer.

The fish present were bluegills (Lepomis machrochirus), sunfish (Lepomis gibbosus), bullheads (Ameiurus melas), yellow perch (Perca flavescens), minnows, very few smallmouth bass (Micropterus dolomieu), and many hybrids between the bluegill and sunfish. The centrarchids were reported as growing at a normal rate for the state of Michigan (Crowe, 1947), but they appeared thin and few large ones were present in the lake. The perch showed definite signs of stunting and the lake had the reputation of a very poor fishing lake.

The aquatic plant beds were quite sparse in the lake and consisted chiefly of two species of pondweed, Potamogeton amplifolius and P. natans, and the white water lily, Nymphaea odorata.

South Twin Lake (Cheboygan County).—This lake, which is situated about 500 feet south of North Twin Lake, is separated from it by a low ridge. Although a larger lake (54 acres), it has a maximum depth of only 4 feet. The fish population included largemouth bass (Micropterus salmoides), pike (Esox lucius), and bluegills (Lepomis machrochirus). The fish of the lake were not stunted and the fishing of the lake was reported as "fair" at the time the fertilization of North Twin was undertaken.

Judging from the age of some of the game fish from the lakes and reports of sportsmen of the area, it was evident that there had been no winterkill in these lakes for at least 10 years.

Description of Trout Lakes

South Twin and North Twin lakes in Otsego County are small solution lakes. They are very similar in basin size and shape, and in the chemical constitution of their waters. The south lake has a surface area of 4.3 acres and a maximum depth of 39 feet. These lakes have a firm sand bottom on the steep basin slope to a depth of 15 feet and below this depth a thin covering of organic muck. Sparse stands of both broad-leafed and narrow-leafed potamogetons are scattered around the rims of these lakes and extend to a maximum depth of 20 feet.

The lakes have no inlet or outlet, their levels depending upon the ground water level since there is virtually no surface drainage into the lakes. These lakes are important because they are trout waters and also are a scenic attraction due to the unusual beauty of their extremely clear blue waters contrasting with the green of the surrounding large pines.

At the beginning of the experiment the lakes had fish populations which included many small perch, minnows, a few large rainbow and brown trout, and brook trout. The minnows and perch presumably were brought in by fishermen, either intentionally or as bait; the brown and rainbow trout were remnants of plantings made before the policy

of planting only brook trout in lakes was established. The lakes are stocked each fall with fingerling brook trout. Trout fishing has not been good in the lakes for some time due to the competition and predation of the perch.

Analysis, Concentration, and Distribution of Fertilizer

Fertilization was started in June, 1946 and continued until September of that summer. Fertilization was resumed in May of 1947 and continued throughout the summer, the last application being on August 20, 1947.

On the basis of soil samples analyzed at Michigan State College it was recommended that a high nitrogen, high phosphorous fertilizer be applied and a 10-6-4 commercial fertilizer was recommended. A tentative fertilization schedule was established at three week intervals and later proved quite satisfactory. The fertilizer was spread on the larger lake, (North Twin, Cheboygan County) by pouring from a moving boat, and on the smaller lake, (South Twin, Otsego County) by scattering from shore.

The volume of fertilizer to be applied was established at 2 p.p.m. per week. This was a total of 2,800 pounds for each three-week application on the warm-water lake and 400 pounds for the small trout lake. This amount was applied during the summer of 1946 and proved to be satisfactory in the shallow North Twin Lake but not adequate to bring about a plankton bloom in the colder, deeper waters

of South Twin Lake. The amount of fertilizer was increased to 3 p.p.m. per week for the trout lake in 1947 which resulted in an increase in the amount of particulate organic matter but did not produce a bloom.

Chemical Analyses of the Lakes

Chemical analyses of the two trout lakes, made in June, 1946, just prior to the first application of fertilizer, showed them to be very similar in all respects. The total alkalinity was 48 p.p.m. in the south lake and 42 p.p.m. in the north lake. No further analyses were made until late October of the same year at which time both lakes were in the late stages of the fall overturn period and conditions were uniform from top to bottom. The only change noted was in the higher total alkalinity (58 p.p.m.) in the fertilized lake while the unfertilized lake was 41 p.p.m.

Four series of chemical analyses were made during the summer of 1947. These showed changing conditions that reached a peak in August, the period of the summer considered to be the most critical for trout lakes in Michigan. The physical and chemical conditions recorded for the lakes in August, 1947 are shown in Table 1.

From the data in Table 1 can be seen a tendency toward eutrophication in South Twin, the fertilized lake. The thermocline was higher in this lake with an accompanying oxygen depletion in the hypolimnion. The upper level of the thermocline was about 8 feet below the surface of the lake and extended to approximately 20 feet in the fertilized lake, while in the north lake (unfertilized) it was of the same thickness but the upper limit was 18 feet below the surface and the lower limit at 30 feet.

Table 1.—Chemical and temperature data for North Twin and South Twin Lakes, Otsego County, August 20, 1947.

	North Twin (unfertilized)						South Twin (fertilized)					
Depth in feet	Temperature °C.	O_2	CO_2	Phen. alkalinity[1]	M.O. alkalinity[2]	pH	Temperature °C.	O_2	CO_2	Phen. alkalinity[1]	M.O. alkalinity[2]	pH
S	25.0	9.3	0	0	38	7.4	25.0	9.2	0	4	72	7.3
3	...	...	...	...	...	...	...	...	...	...	...	...
6	...	...	...	...	...	...	24.5	...	...	...	...	...
9	...	...	...	...	...	...	22.4	...	...	...	...	...
12	...	...	...	...	...	...	19.0	...	...	...	...	...
15	24.5	...	...	...	...	...	14.3	...	...	...	...	...
18	23.5	8.8	0	0	36	7.0	10.1	7.3	3.0	0	72	7.0
21	18.1	...	...	...	...	...	8.6	2.2	...	...	...	...
24	12.5	...	...	...	...	...	8.1	0.0	...	...	...	...
27	8.1	...	...	...	...	...	7.8	...	...	...	...	...
30	7.5	8.0	...	...	...	...	7.5	...	...	...	...	...
33	7.1	0.0	5	0	39	6.9	7.1	0.0	7.0	0	78	6.7
36	7.1	...	...	...	...	...	7.1	...	...	...	...	...
39	...	...	...	...	...	...	...	...	...	...	...	...

[1] Phenolphthalein alkalinity
[2] Methyl orange alkalinity

In the fertilized lake the oxygen was depleted near the lower level of the thermocline, thus limiting the fish of the lake to the stratum above a depth of 20 feet, while in the untreated lake there was sufficient oxygen to support fish life in the upper 30 feet. However, the strata considered as trout water were of almost identical size in the two lakes, the difference being the depth at which they occurred. The oxygen distribution in the two lakes is shown graphically in Figure 1.

The temperature of the upper 15 feet of water in South Twin (fertilized) was lower than in North Twin at the time of the August chemical analysis. This lower temperature may be attributed to the plankton organisms, resulting from fertilization, preventing the penetration of heat rays into the water. At the time the temperature series was taken the Secchi disk reading was 8.2 feet in the fertilized lake and 22.1 feet in the unfertilized lake.

A lowering of the water temperature was noted by Eicher (1947) following an application of Nigrosine in an experiment on aquatic weed control. He attributed the lower temperature to the dye preventing the infra red rays from penetrating far below the surface. This maintenance of a temperature closer to that of accepted trout water is desirable, but trout were observed rising on the surface of the untreated lake in which the upper 20 feet were at a temperature above 68° F., thus indicating that the warmer waters did not serve as a complete barrier to trout.

The differences in temperature gradients of the two lakes are shown in Figure 2.

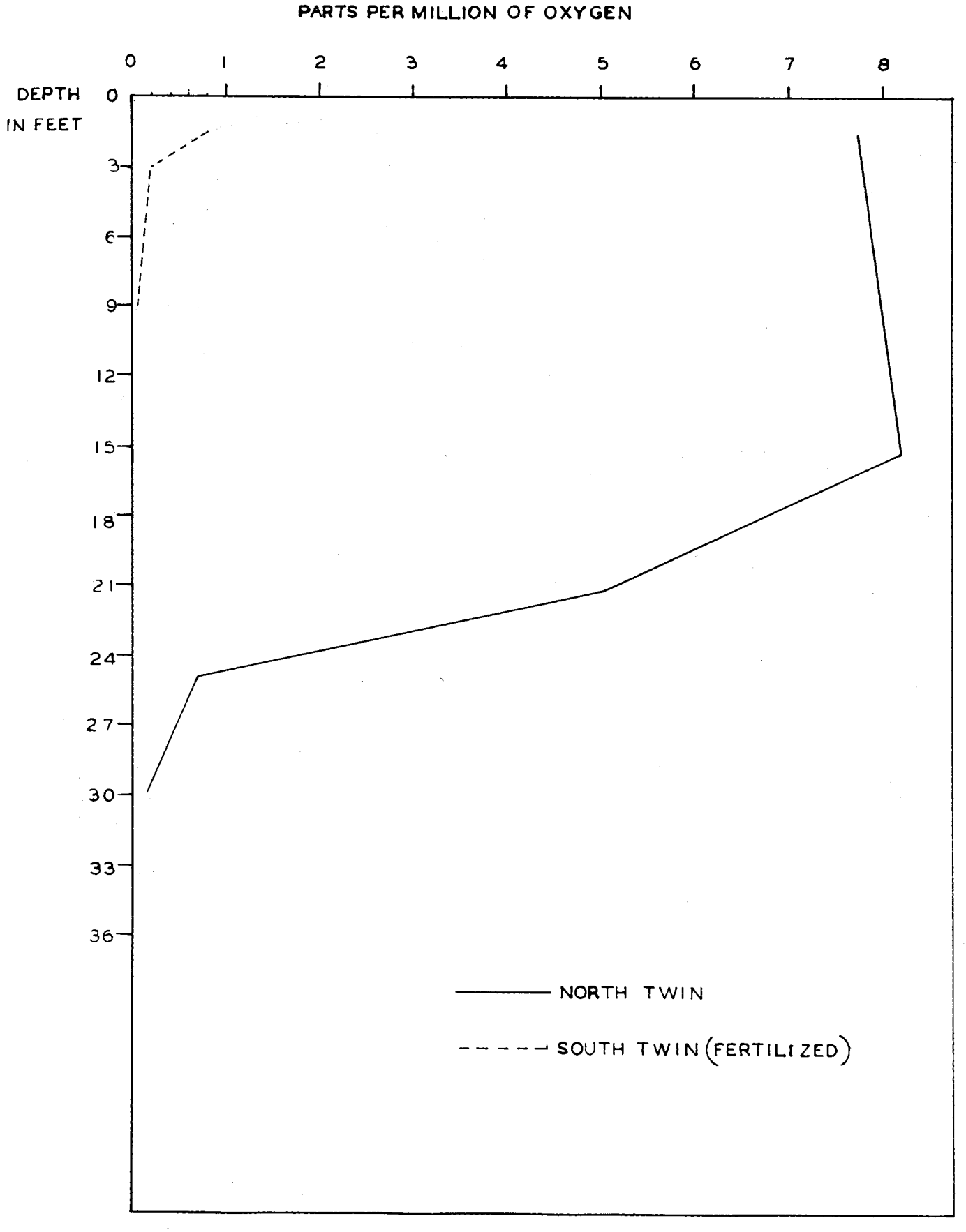

Fig. 1. Difference in oxygen concentration in a fertilized and an unfertilized lake, August, 1947.

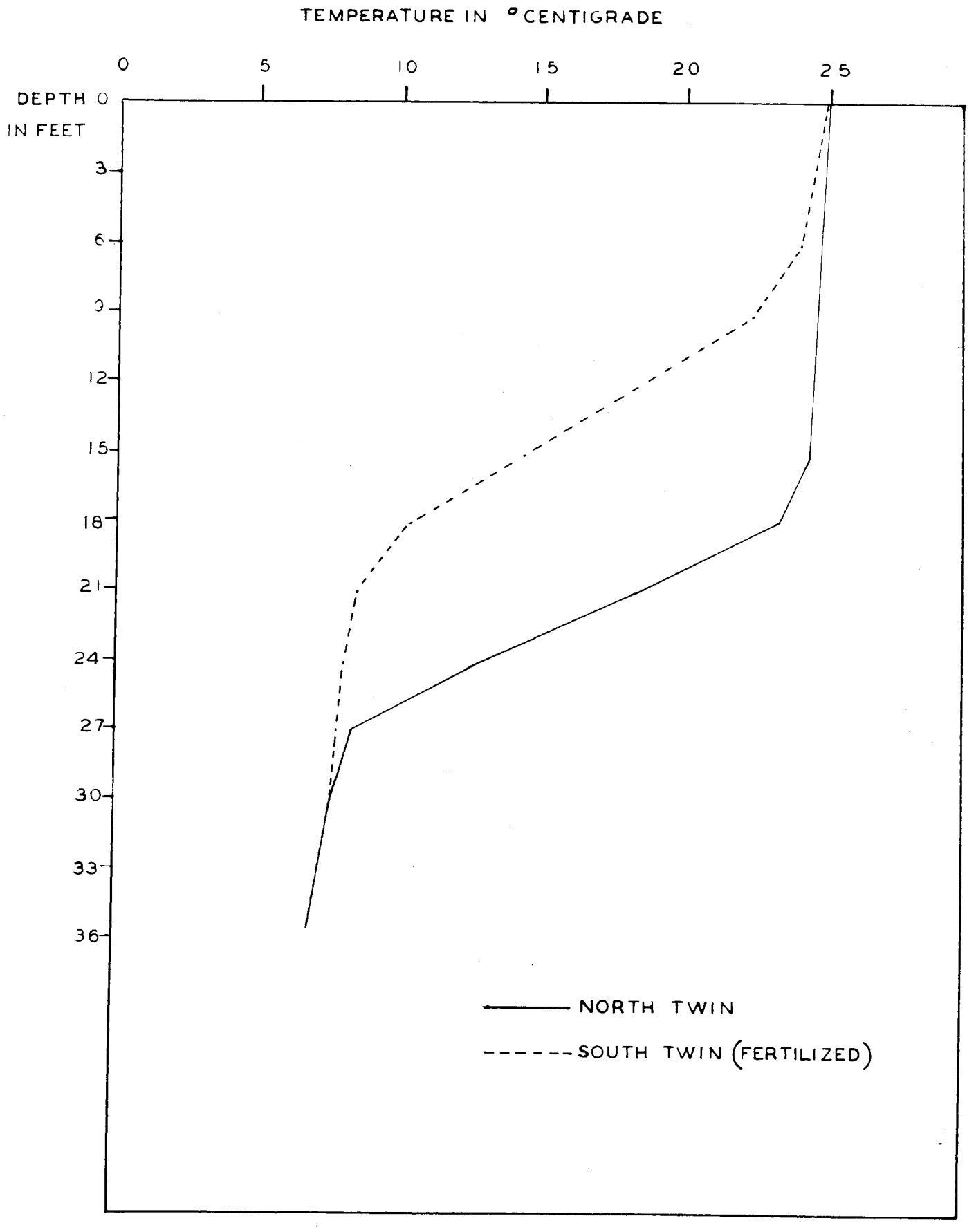

Fig. 2. Temperature gradients in a fertilized and unfertilized lake, August, 1947.

Biological Effects of Fertilization

North Twin Lake (Cheboygan County).—Chemical analyses were made at regular intervals during the summer of 1946, and at weekly intervals during the summer of 1947 on the warm-water fertilized lake (North Twin, Cheboygan County). The results of these analyses will be included in a later report (Ball and Tanner, MS) but it is sufficient to note that there was oxygen from top to bottom of the lake during the entire open water season and the water of the lake was moderately hard (50 p.p.m.). This shallow, warm-water lake responded to the addition of fertilizer very shortly after the first application and maintained a heavy bloom of plankton algae throughout the summer. The Secchi disk reading ranged between a depth of 18 and 36 inches throughout the summer. The sparse beds of higher aquatic plants became covered with a coating of algae, turned brown and died.

The pulpy peat bottom material, which came within a foot of the surface at the shallow end of the lake, appeared to liquefy as the first summer of fertilization progressed. No qualitative measure of this was made but general observations indicated a definite change in its color and physical nature believed to be associated with active decomposition, presumably brought about by the addition of nitrogen and phosphorous.

The results observed the second summer were quite different in many respects. Until midsummer very little plankton algae was present in the lake, but great mats of filamentous algae covered the shallow areas. This growth died down about midsummer and for a period of

approximately 10 days the dead and decaying mat of plant material drifted about the lake creating an unsightly and malodorous condition. Following the disintegration of the filamentous algae the lake became cloudy with plankton algae and this condition existed for the remainder of the summer.

South Twin Lake (Otsego County).—The effects of the fertilizer on this small trout lake were quite different than those observed on the warm-water lake. At no time in the two summers was the Secchi disk reading less than 8 feet. There was a definite increase in suspended organic matter in this lake as shown by comparison with its control (North Twin, Otsego County) in which the Secchi disk was visible at 20 feet or more during the entire summer.

In the fertilized lake the logs, stones, and higher aquatic vegetation were heavily coated with filamentous algae, the higher aquatic plants being covered to such an extent that growth was limited and many died. This plant covering of the logs, etc., created an unsightly condition when it loosened and floated to the surface during the latter part of the summer.

Winter Conditions, 1947

A check on the warm-water lakes was made in January, 1947, at which time the chemical analyses showed no severe depletion of oxygen in either lake and carbon dioxide levels were not high. The oxygen level in the North (fertilized) lake was somewhat higher than in the South lake, a condition due probably to the partial removal of the snow cover by wind action. Greenbank (1945) found that ice, even though

cloudy, permits the penetration of a considerable amount of light, while even a few inches of snow on the ice reduces the amount of light reaching the lake to a point where no photosynthesis occurs.

No check on the trout lakes was made at this time as they were inaccessible due to deep snow. All lakes were visited when the ice cover was breaking up and no signs of dead fish were seen.

Winter Conditions, 1948

A check of all four lakes was made during the last week of February, 1948. This period of the winter is believed to be the most critical one for the lakes as the snow and ice cover has been on almost its maximum length of time and winter stagnation conditions are at the maximum.

Warm-water lakes.--At the time of the winter check these lakes were covered with a 7 inch cover of clear ice on top of which was about 8 inches of snow ice.

An analysis of the water of the North Lake showed the oxygen level to be very low, 0.7 p.p.m. at a depth of 2 feet and 0.2 p.p.m. at 10 feet. The carbon dioxide level was high, 40 p.p.m. at the 10 foot level. Upon breaking through the ice cover the odor of decay was very strong and many dead phantom midge larvae (Chaoborus) floated into the hole. Deeper samples indicated the presence of a considerable amount of hydrogen sulfide.

Bottom samples taken by means of a dredge at several locations on the lake revealed that many species of invertebrates, including scuds, damselflies, dragonflies, caddisflies, and adult beetles were dead. The large midge larvae, Chironomus plumosis, were alive but quite inactive.

No dead fish were found at this time, but large numbers were found at a later visit just prior to the break up of the ice. A check during the following spring and summer revealed that a small number of perch had survived the unfavorable conditions, while most fish had died.

A chemical analysis of the South lake revealed conditions that were similar in many ways. The oxygen level had been reduced to 0.3 p.p.m. at several locations in the lake. The oxygen analyses were all run in duplicate and aerated samples run as checks. On this lake the carbon dioxide concentrations were low (8 p.p.m.) and no odor of decay or hydrogen sulfide was noted. No dead insects were found and a check at the time of the ice cover breaking up revealed no dead fish. It is difficult to believe that oxygen concentrations as low as these would not cause the death of fish, but checks on many lakes by Cooper and Washburn (1948, in press) have indicated that fish can tolerate lower oxygen concentrations than generally regarded as lethal.

Trout lakes.—The small trout lakes were checked during the same period and chemical analyses run on both lakes. On these lakes the undesirable effects of fertilization were very much in evidence. Both lakes had a clear ice cover of about 10 inches and snow cover of about 8 inches.

Conditions on the unfertilized lake, North Twin, were quite satisfactory for the survival of fish. There was ample oxygen for aquatic life to a depth of 21 feet or more and the carbon dioxide concentrations were low.

Conditions were very different in the fertilized lake, South Twin, where the oxygen concentration did not exceed 0.6 p.p.m. at any depth and was less than 0.2 p.p.m. at a depth of 3 feet. The carbon dioxide level was 18 p.p.m. at 3 feet. Here, too, the odor of decay was strong and dead Chaoborus floated into the hole in the ice cover. The oxygen concentrations in the two lakes at the critical stage are shown graphically in Figure 3.

Growth of Fish in Fertilized Lakes

The winterkill terminated the study of the effects of fertilization on increased growth of fish in these lakes before enough evidence had been collected to enable us to evaluate adequately the several factors to be considered in such a study. However, from a study of the scales collected during the two years of the experiment, and after the winterkill, it is quite evident that the growth rate of the fish had increased considerably.

There is the possibility that the fertilization had an adverse effect on the reproduction of the fish in the lake. During the 1947 spawning season of the centrarchids the entire shoal area of North Twin Lake (Cheboygan County) that was suitable for spawning was covered with a dense mat of filamentous algae that appeared to interfere with the building of nests by the fish. The nests observed were relatively small openings cleared in the algae and it was observed that many apparently active nests were abandoned because of envelopment by the algae. There was some spawning activity after the filamentous algae was gone but extensive seining late in the season collected very few young of the season fish.

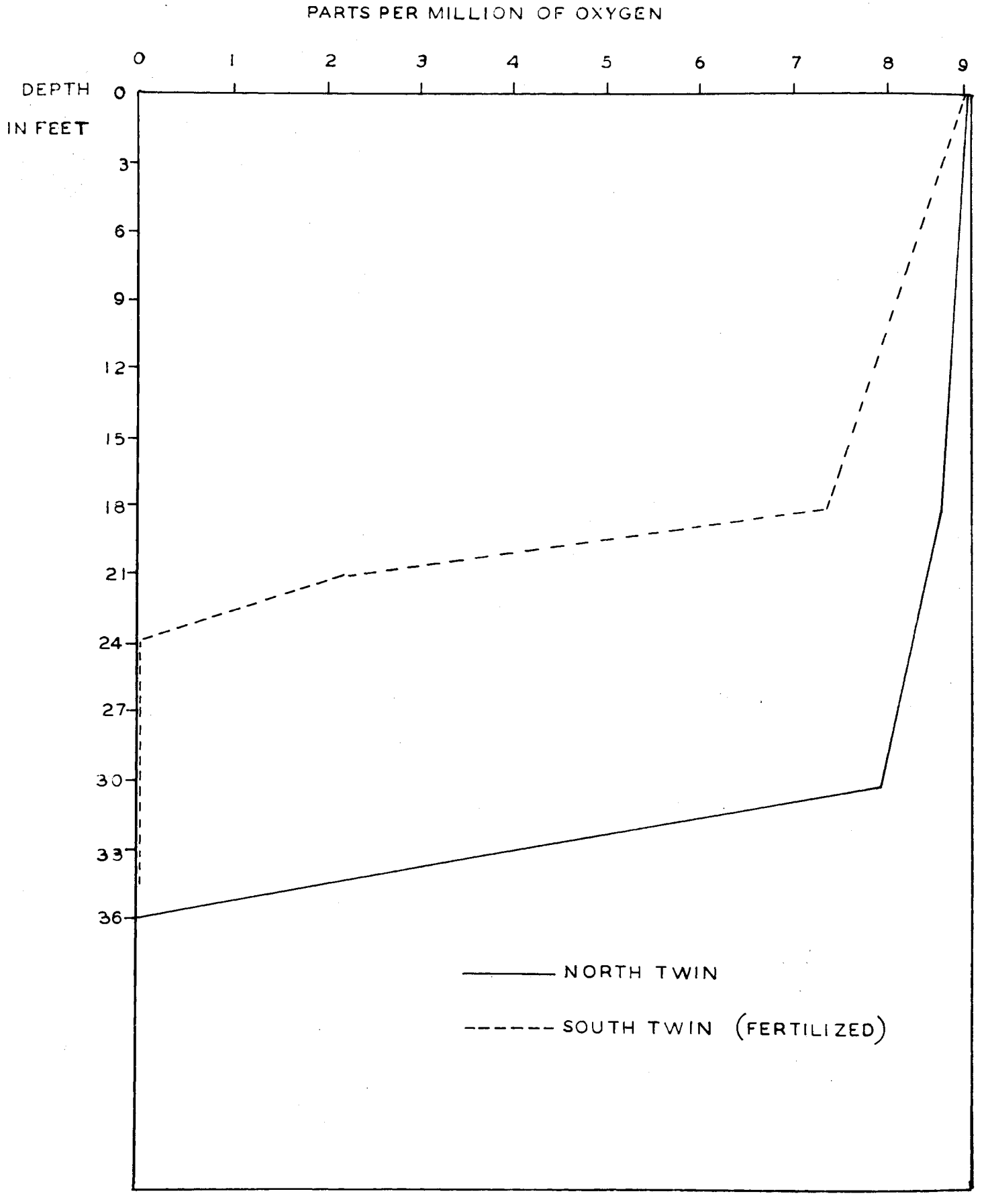

Fig. 3. Oxygen concentrations in a fertilized and unfertilized lake at critical period of year, 1948.

Experimental use of fertilizer as applied to a trout lake in New Brunswick (Smith, 1948) appeared to have no ill effects during the winter following the first year's application. It was presumed in the report on this lake that the volume of invertebrates in the bottom fauna had been increased by the fertilizer since the average volume of food in trout stomachs taken from the lake was four and a half times the average found for the same period of the preceding year. That fertilizer will increase considerably the invertebrate fish food organisms has been shown (Ball, in press) by recent work on small ponds in Michigan.

Summary

The fertilization of two unproductive northern Michigan lakes resulted in a severe winterkill in both lakes during the winter following the second summer of fertilization. That this kill was due to the effects of the fertilizer seems certain since no such kill occurred in the two lakes serving as controls. The question as to whether a lesser amount of fertilizer would have produced an increase in the growth rate of the fish without setting up conditions that lead to winter oxygen depletion is not known, but is under consideration at the present time.

At no time did the plankton bloom in North Twin Lake (warm-water lake) reach the concentration that has been recommended as the level to be maintained in southern ponds (Swingle and Smith, 1942) and the bloom attained was always on the wane before the end of the three week fertilization period.

No bloom was present in South Twin (trout lake) at any time during the two summers.

It has been stated (Deevey and Bishop, 1941) that low productivity is one of the potential characteristics of most trout lakes, and from these experiments it appears that by artificial enrichment of a trout lake it is possible to so alter its characteristics that it will be modified in the direction of an eutrophic, or warm-water fish lake. The changes notes in this trout lake may be only transitory, but until more evidence as to their duration and importance is obtained it seems that fertilization of lakes in the latitude of Michigan should be confined to experimental work.

In considering the fertilization of a lake the nuisance factor of a high production of filamentous algae should not be overlooked. It is extremely objectionable to fishermen, swimmers, boat operators, and owners of lake shore property.

On the basis of these experiments it is evident that fertilization of natural lakes can have unfavorable as well as favorable results, and until such a time as we can more accurately predict the amounts of fertilizer adequate to increase the productivity of a lake without the accompanying depletion of oxygen during the periods of ice cover, and can predict or control the type of algae that will be produced, it does not appear wise to sanction or encourage the indiscriminate fertilization of our lakes.

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