9-15-1936

A cause of death of fish in the Southwest.

John D. Clark

John Greenbank

The University of New Mexico Bulletin

A CAUSE OF DEATH OF FISH IN THE SOUTHWEST

JOHN D. CLARK

and

JOHN GREENBANK

THE UNIVERSITY OF NEW MEXICO BULLETIN

Whole Number 294 — September 15, 1936

Chemistry Series, Volume 2, No. 4

Published twice a month by the University of New Mexico
Albuquerque, New Mexico

Entered as Second Class Matter, May 1, 1906, at the Post Office at Albuquerque, New Mexico, under Act of Congress of July 16, 1894

UNIVERSITY OF NEW MEXICO PRESS
1936

FOREWORD

During the past quarter of a century, throughout the Southwest, fishing as a recreation has assumed a position of major importance. A quarter of a century ago a few individuals fished for the native fishes. These individuals *were few*. Likewise the species of fish were few. Native trout were found in the mountains. Buffalo, catfish, and carp lived in the warm, but permanent, streams. There were no fish hatcheries, and such few fish as were in the waters had little or no protection afforded them by law. Stream improvement was unknown. Water reservoirs were few and far between. Fishing tackle was seldom displayed in the stores. In general, people just didn't go fishing.

In contrast to the conditions of a few years ago, we find today a liberal variety of fishes in our, now, much more abundant waters. The states maintain hatcheries for cold-water fish, and Federal hatcheries rear warm-water species. Distribution runs into millions of fish each year, and each year the fish are kept for a longer time in rearing ponds and are larger when planted. Fish and game laws are adequate, and well administered; and, by and large, are well observed by sportsmen. Streams constantly are being improved. New bodies of water have been created. Examples are, to cite only a few in New Mexico alone: Elephant Butte Reservoir, El Vado Reservoir, Bluewater Reservoir, Eagle Nest Lake, and the three hundred miles of drainage canals in the Middle Rio Grande valley. Strangers to the Southwest, window-shopping in our cities, are amazed at the many displays of fishing equipment; and ask where there can be so much fishing in a land which appears, from the principal highways, to be semi-arid. Game departments are expending larger and larger proportions of their budgets to supply fishing, even though big game and upland game need more and more attention. In short, while it is not literally true, it seems that now, *everyone* is going fishing.

The most recent phase of fish production to receive attention is the application of chemical and biological science to the problems of securing an increased supply of fish. Lately the United States Bureau of Fisheries has studied the waters of some of our national forests.[1] As a research project by the New Mexico Game Commission, in co-operation with the University of New Mexico, the canals of the Middle Rio Grande valley have been studied.[2,3] A study of the waters of Elephant Butte Reservoir, similarly conducted, is soon to be published.[4] Chemical and biological studies have been made at the hatcheries.

On several occasions during the past five or six years, instances have arisen in New Mexico where, as if the catastrophe were the matter of a moment, all or part of the fish in some body of water have been found dead. And each time the question was presented to the chemistry department of the University of New Mexico: What killed the fish? In each case so reported to the department, someone has gone to the waters to attempt to account for the loss.[5] In one case a fish disease seemed to explain the deaths; but in most cases no evidence of disease or parasite infestation appeared. In some of the cases lack of oxygen seemed to be a cause; but by the time the investigators reached, and analyzed, the water, the oxygen supply was found to be adequate, although not abundant. Poisons in the waters were suspected at times, but chemical analysis always failed to reveal them. The spectacular explanation—dynamite—

1. Stream surveys of the national forests and parks. *Science*, 81:310, March 29, 1935.

2. Clark, John D. and Smith, Hillard L. A chemical study of the waters of the Middle Rio Grande Conservancy District as related to fish culture. *Bulletin* 270, University of New Mexico, July, 1935.

3. Shettles, Landrum B. Some biological aspects of fish culture in the Middle Rio Grande Conservancy drains. Thesis, University of New Mexico Library.

4. Clark, John D. and Greenbank, John. A chemical and biological study of the waters of Elephant Butte Reservoir as related to fish culture. *University of New Mexico Bulletin*, to be published.

5. A brief account of one of these investigations, made by the junior author of this paper, is given in the *New Mexico Magazine*, Santa Fe, New Mexico; November, 1935.

was always advanced, but in none of the cases where the dead fish were examined was it substantiated.

On or about the morning of July 7, 1936, at Park, or Stink, Lake, near Santa Rosa, New Mexico, dead fish were everywhere. Apparently no one attempted to count them; but the junior author was told there were "scads" of them.[6] State Game Warden Elliott S. Barker sent a sample of the water from the lake to the chemistry department of the University. Analysis revealed a high content of mineral salts in the water, half of which was due to sulfate (SO_4). There was free hydrogen sulfide (rotten egg gas) in the water. Recommendation was made to Warden Barker that the waters be studied *at the lake,* which recommendation was approved; and on July 23, 1936, the study was made by the junior author.

The results of this examination are the subject of this bulletin. The bulletin is being published because it gives a well substantiated, and well explained, case of fish loss, *which may occur in any of the smaller bodies of water in the Southwest.* It also suggests means of prevention of such losses, though it should be stated that the suggested means need to be studied as an experimental project. There are hundreds of small bodies of water in the state which have been stocked with fish, even the so-called "tanks" on the ranches. If these sudden losses of fish can be prevented, much time and money spent in stocking will be saved; and the way to still further increase food, and recreation, in the yet unstocked small bodies of water (for example, in the small reservoirs being made by soil conservation work) will be made clear.

Clarke[7] points out that while the waters of the eastern United States are characterized by their carbonate content, those of the West and particularly the Southwest, have a prevalence of sulfates. The Santa Rosa lakes are excep-

6. In the course of his investigation, the junior author estimated that practically 100 per cent of all of the fish in the lake, with the exception of a few small ones, had been killed.

7. Clarke, F. W. Data of Geochemistry. *U. S. G. S. Bulletin* 491, 1911.

tionally rich in sulfates. They are located in sink holes (for which the area is famous) caused by the solution and disappearance of underlying strata of gypsum. This sulfate content has a direct bearing upon the obtaining of data in this study; for in waters of lower sulfate content, although the same phenomenon might occur, the evidence would be less concrete and striking.

Sudden losses of fish, difficult to explain, are not new. An interesting case has been reported from Connecticut,[8] in which the fish in a small pond apparently died from suffocation, after a heavy rain had washed decaying organic debris into the pond. And a very striking instance of sudden fish mortality occurred a few years ago in a salmon stream in Alaska.[9] Here approximately five thousand fish perished within thirty minutes, probably of suffocation.

In the case at hand, at about midnight before the loss occurred, a woman was at the lake, and reported an unusual stench. The next morning the fish were found dead. What did that stench have to do with the death of the fish? The rest of this bulletin will reveal the details of the explanation. Very briefly, what probably happened is as follows: Hot weather caused an abundant growth of algae, which used, on the whole, more carbon dioxide than it gave off. At the same time it liberated more oxygen than it used. Then, for some reason, much of this plant growth died. In decaying it began to give off carbon dioxide, and to consume the oxygen needed by the fish. Furthermore, in this particular water, the dead organic matter began to reduce the harmless sulfates to harmful sulfides. Carbon dioxide released hydrogen sulfide. What happened to distribute this poisonous substance throughout the lake, already lacking in oxygen, and thus to kill practically all of the fish, is unknown. However, it can happen again, in this and in many other bodies

8. Tomlinson, David. Rare aquatic phenomena. *Science*, 82:418, November 1, 1935.

9. Davidson, Frederick A. Temporary high carbon dioxide content in an Alaskan stream at sunset. *Ecology*, 14:238-240, April, 1933.

of water in the Southwest—hence this bulletin is being published.

As an experimental study it is suggested that a windmill be erected upon the shore of the lake, that the windmill be connected to an air pump, and that air be pumped into the deeper portion of the lake. Data then should be collected throughout the year, to determine the efficiency of such aeration. Already small blowing units have been developed for shallow lakes around some fish hatcheries in Iowa.

A CAUSE OF DEATH OF FISH IN THE SOUTHWEST

Introduction

It is the purpose of this paper to deal first with a chemical investigation which was made of the water of a small, shallow lake near Santa Rosa, New Mexico, in an effort to ascertain the cause of the sudden death of the fish in this lake; and second, with the possibility of applying the results obtained in this investigation to the bettering of conditions in many similar shallow lakes of the Southwest.

Park Lake, or "Stink Lake," is located just outside of Santa Rosa. It is about 200 yards in diameter, and is of a fairly uniform depth of from nine to twelve feet. It derives its water supply from an underground flow, and has practically no overflow. It has been stocked with large-mouth black bass; and, considering its size, it has afforded fairly good fishing. So the sudden death of practically all of the fish in this lake, about July 7, 1936, was regarded in the light of a catastrophe. In view of similar occurrences in the past[10], in which sudden death of fish was caused by abrupt chemical change in the water, some such chemical disturbance in this lake was suspected; and the investigation which is here described was undertaken.

The field work, sponsored by the New Mexico State Department of Game and Fish, was done by the junior author of this paper, July 23-24, 1936, under the supervision of the senior author, and in co-operation with the University of New Mexico. Valuable aid was rendered by Mr. Alfred Irvin, of Santa Rosa, and by Mr. Parrish, of the Federal fish hatchery at Santa Rosa.

The field methods used were similar to those used in fish survey work by the United States Bureau of Fisheries.[11]

Paralleling this investigation, a brief chemical study also was made of Club Lake, which was assumed to be typical

10. Cf. footnotes 8 and 9.

11. The various chemical determinations are described in such textbooks as *APHA Standard Methods of Water Analysis*.

of the several deep, yet small, lakes of the region. The contrast in the chemical conditions of the two types of lakes, the deep and the shallow ones, in the same locality and with the same water supply, is striking, and will be enlarged upon below.

PHYSICAL AND CHEMICAL FACTORS

That which is spoken of as the "water" of a lake, pond, or stream is in reality an intricate chemical complex. In addition to water itself, it contains various dissolved solids (salts), often suspended inorganic and organic material and always dissolved gases. Some of the substances contained in the water may, in certain amounts, be harmful to fish. Many others of these substances are, in the proper proportions, distinctly beneficial and even strictly necessary to fish life. Fish, and the majority of all other forms of aquatic life, would die in a few minutes, or at the most in a few hours, if placed in *absolutely pure water*.

In addition to the influence of the *chemical* substances in the water upon the life within it, there also exists the influence of certain *physical* factors, such as the temperature of the water.

A very brief summary of some of the more important chemical and physical factors of natural waters, in relation to the life of fish, will now be given. Clark and Smith[12] give a review of the extensive literature concerning these factors, and an easily understandable description of their operation.

TEMPERATURE

For any species of fish there is a range of temperatures *best suited* to the species, and also an extended range of temperatures which it can *tolerate*. But although water temperature is all-important when cold water species (such as trout) are dealt with, it usually is of minor concern in considering warm water species (such as bass). Warm weather

12. Clark, John D. and Smith, Hillard L. "A Chemical Study of the Waters of the Middle Rio Grande Conservancy District as related to Fish Culture." *Bulletin* 270, University of New Mexico, July 15, 1935.

fish are able to withstand relatively wide temperature ranges; and the waters in which they are propagated are usually of about the most desirable temperatures.

However, the indirect effect of water temperature, its influence upon the growth or decay of water plants and upon the content of various dissolved gases in the water, may become of grave importance to the life of even warm water fish.

PHYSIOGRAPHY

Features of a body of water such as size, shape, and depth, have little, if any, direct bearing upon fish life. They may, though, exert an influence upon other physical or chemical properties of the water, which in turn may have a marked effect upon fish. There is, for example, the fact that a shallow lake is much more easily and more often mixed by wind and current action than is a deeper one; and hence the shallower lake usually shows a more uniform physical and chemical structure. As will be shown below, in the case of Santa Rosa Park Lake, this ease with which a shallow lake becomes mixed may at times become very undesirable, even disastrous.

DISSOLVED SOLIDS

As far as direct effect upon fish is concerned, it is only occasionally that there is either a dearth or an overabundance of any of the mineral substances which are commonly present in natural waters. Sometimes, however, these dissolved substances change the acidity or alkalinity of the water; and hence influence the growth of plants and of animals in the water, and sometimes the growth of fish themselves.

Again, certain of these dissolved solids may enter into chemical reactions which entirely change the amounts and kinds of dissolved gases in the water. For instance, if carbonates or bicarbonates come into contact with mineral or organic acids, carbon dioxide may be set free. This ability of dissolved solids to effect chemical changes involving dissolved gases will be elaborated upon below, in the explanation of what probably took place in Park Lake.

ACIDITY AND ALKALINITY

In general, fish can tolerate comparatively wide ranges of acidity and alkalinity. So here again the principal effects are indirect. Acidity or alkalinity has an influence upon the fish food supply; since different water plants and animals thrive under different conditions of acidity or alkalinity. Sometimes acidity and alkalinity have an influence upon dissolved gases. But, on the whole, it is probable that only seldom is a body of water too acid or too alkaline to support fish.

CARBON DIOXIDE

The gas, carbon dioxide (CO_2), is intimately connected with aquatic life in general. Normally, in nature, both on land and in the water, it passes through a continuous cycle. Growing plants, under the influence of light, *take up* carbon dioxide, and synthesize food material. The respiration, or burning up, of this food material in the animal body again *releases* carbon dioxide. It is also set free by the decay of dead plants and animals.

Thus, in a body of water, as long as water plants are in a growing condition (in the spring and early summer) they are taking up more carbon dioxide than they are giving off. But this condition is reversed when the plants are in a state of decay (in the fall and winter). Then carbon dioxide is being released, and oxygen is being consumed. Thus the carbon dioxide content of the water may change from time to time, and from season to season.

Carbon dioxide will combine with carbonates and hydroxides, if any of these are present; and hence it is less apt to occur free in the more alkaline waters.

Carbon dioxide, if present in very large amounts, is suffocating and poisonous to fish. The amount of the dissolved gas which fish can tolerate varies widely, depending upon the species of fish, the amount of dissolved oxygen present, and the temperature of the water. Probably, under ordinary conditions, no fish is seriously harmed by the presence of twenty to forty parts per million[13] of free carbon dioxide; and, under certain conditions, perhaps much more can be tolerated.[14]

DISSOLVED OXYGEN

As do land animals, fish require oxygen for their survival. Their only source of this oxygen is that which is dissolved (as a gas) in the water (the O of the H_2O is totally unavailable to fish). If the supply of dissolved oxygen becomes depleted, fish die.

Oxygen is supplied to the water by the atmosphere, and by the food-manufacturing process of growing plants. It is taken from the water by the decay of plant and animal remains, by the respiration of plants and animals, and by loss to the atmosphere. Also, it may at times be added to, or at times taken from, the water by chemical reactions involving inorganic substances.

The amount of oxygen which is necessary to sustain fish depends upon many factors. It varies especially with the water temperature. As respiration and rate of growth are more rapid at elevated temperatures, it may be readily seen that with increasing temperatures, the demand for oxygen is increased. It varies with the species. It varies with the amount of carbon dioxide present, more oxygen being necessary if the carbon dioxide content is high.

Therefore, it is difficult to set an arbitrary quantity of oxygen as being the minimum amount required. Probably, for most fish, under average conditions, 2 p. p. m. is dangerously low; while 4 p. p. m. or more is safe.[15]

---

13. By weight. Abbreviated: p. p. m.

14. Cf. Gutsell, James S. "Influence of Certain Water Conditions, Especially Dissolved Gases, on Trout." *Ecology*, 10:77-97, January-October, 1929.

15. See Gardner, J. A., and others. "The Respiratory Changes in Fresh-water Fish." *Ecology*, 10:77, January, 1929.

HYDROGEN SULFIDE

Of the various gases which *occasionally* may be dissolved in natural waters, one of the most important is hydrogen sulfide (H_2S). (It is this gas that gives rotten eggs their characteristic odor.) Hydrogen sulfide may enter the water from the decay of sulfur-bearing organic material; or it may be derived, by chemical reaction, from the sulfates often present in the water.

This gas is very poisonous. Its effect upon fish perhaps is indirectly, or perhaps is directly, toxic.[16] At any rate, its presence in large amounts is very harmful.

THE TWO LAKES UNDER CONSIDERATION

As has been stated above, two lakes near Santa Rosa, New Mexico, were studied (July 23-24, 1936) in this particular investigation.

1. *Park Lake.* Area, about eight or ten acres. Depth, eight to twelve feet.

The primary object of the study was to try to ascertain the cause, possibly a chemical one, of the sudden death of fish in this lake, which occurred about fifteen days previous to the investigation.

2. *Club Lake.* Area, about fifteen to twenty acres. Depth, throughout the deeper portions, forty-five to sixty-five feet.

This lake was selected for study as being typical of the deeper lakes of the vicinity, and as offering, in many ways, a distinct contrast to the shallow lake.

COMPARISON

A comparison of the waters of these two lakes yields several points of similarity.

1. They are subject, of course, to the same weather conditions.

16. Welch, Paul S. *Limnology.* McGraw-Hill, New York, 1935. P. 184.

2. They have practically the same border vegetation (cattails, sedges, grasses) and the same submerged vegetation (several forms of algae); hence their environments for supplying fish food are similar.

3. They are both fed by underground water. This water flows through gypsum and limestone formations; hence it is fairly high in dissolved solids, especially calcium sulfate ($CaSO_4$).

4. Neither has pronounced acidity or alkalinity.

5. They are both comparatively clear.

CONTRAST

But about here the similarity ends; and in several important aspects, such as temperatures, and amounts and distribution of dissolved gases, a marked contrast between the two lakes appears. A brief description of the chemical characteristics of each of the lakes will be given below.[17]

PARK LAKE

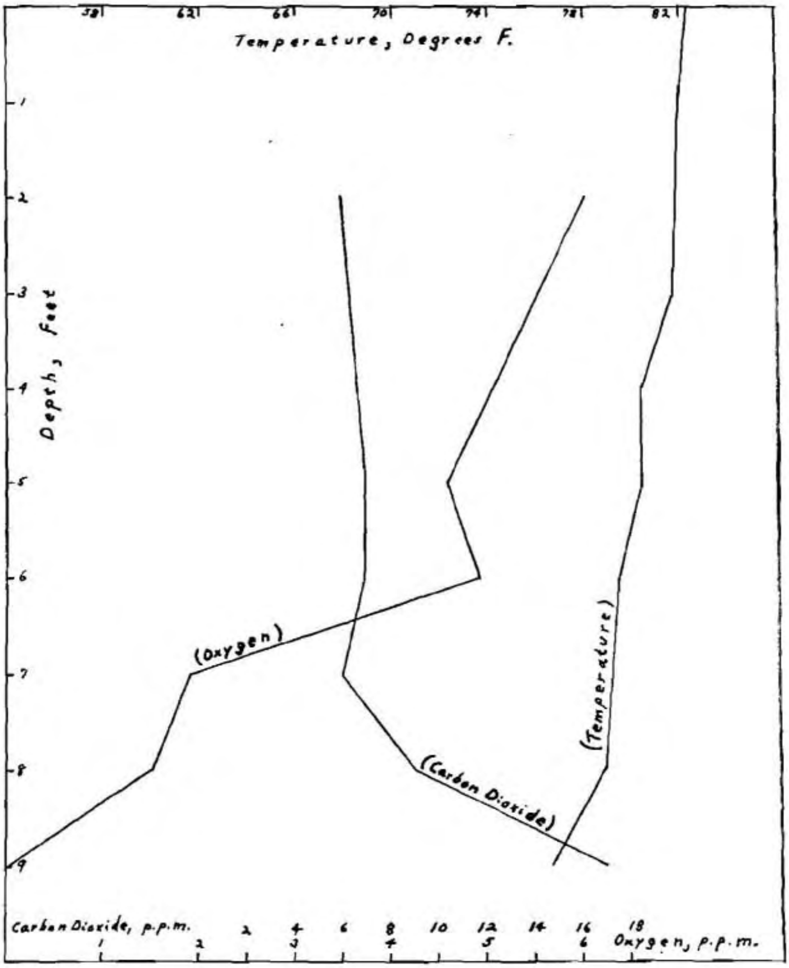
1. *Temperature.* As would be expected in a lake so shallow, the temperature dropped but slightly from the surface to the bottom (see Table 1, and Graph 1). The temperature ranged between the fairly high figures of 24.8° to 28.0° Centigrade, or 76.6° to 82.4° Fahrenheit.

2. *Dissolved oxygen* varied from 6.0 p. p. m. near the surface to 0.0 p. p. m. on the bottom, at a depth of nine feet. (Again see Table 1 and Graph 1.) The sample taken nearest the bottom was taken with the water sampler in among the algae, which everywhere thickly covered the bottom of this lake.[18] The sample of the next depth, eight feet, was taken just above the layer of algae.

3. *Carbon Dioxide.* As shown in the table and graph, carbon dioxide varied from 6 p. p. m. to 17 p. p. m. The

17. It must be borne in mind, of course, that the chemical conditions given are those which existed at a particular given time—namely, July 23-24, 1936. The chemical conditions at some other time or in some other season might be very different.

18. At the time of this study, a large proportion of this vegetation was dead or dying.



GRAPH 1. Temperatures, Dissolved Oxygen, and Free Carbon Dioxide. Park Lake; Santa Rosa, New Mexico. July 23, 1936

TABLE 1

CHEMICAL AND PHYSICAL DATA—PARK LAKE

DEPTH, FEET	TEMPERATURE		DISSOLVED OXYGEN P. P. M.	FREE CARBON DIOXIDE P. P. M.
	DEGREES C.	DEGREES F.		
Surface	28.0	82.4		
1	27.8	82.0		
2			6.0	6
3	27.6	81.7		
4	26.8	80.3		
5	26.8	80.3	4.6	7
6	26.4	79.5	4.9	7
7			1.9	6
8	26.0	78.8	1.5	9
9	24.8	76.6	0.0	17

TABLE 2

CHEMICAL AND PHYSICAL DATA—CLUB LAKE

DEPTH, FEET	TEMPERATURE		DISSOLVED OXYGEN P. P. M.	FREE CARBON DIOXIDE P. P. M.
	DEGREES C.	DEGREES F.		
Surface	26.8	80.3		
1	26.8	80.3		
5	26.6	79.9		
10	26.5	79.7	5.8	3
15	26.1	79.0	3.8	2
18	25.0	77.0	1.0	5
20	23.8	74.8	1.8	4
25	18.8	65.8	4.6	3
30	15.3	59.5		
35	13.3	55.9		
40	12.6	54.7		
45	12.4	54.3	7.0	6
48	12.4	54.3	7.1	6

sample containing the more was taken among the algae at the bottom.

In another place on the lake, at a depth of six feet, samples were similarly taken in, and just above, the algae; and these samples showed 28 p. p. m. and 5 p. p. m. of carbon dioxide respectively.

4. *Hydrogen Sulfide.* A sample taken in the algae, at the nine-foot depth, contained 9.5 p. p. m. of hydrogen sulfide; while a sample taken a foot above the algae contained none.

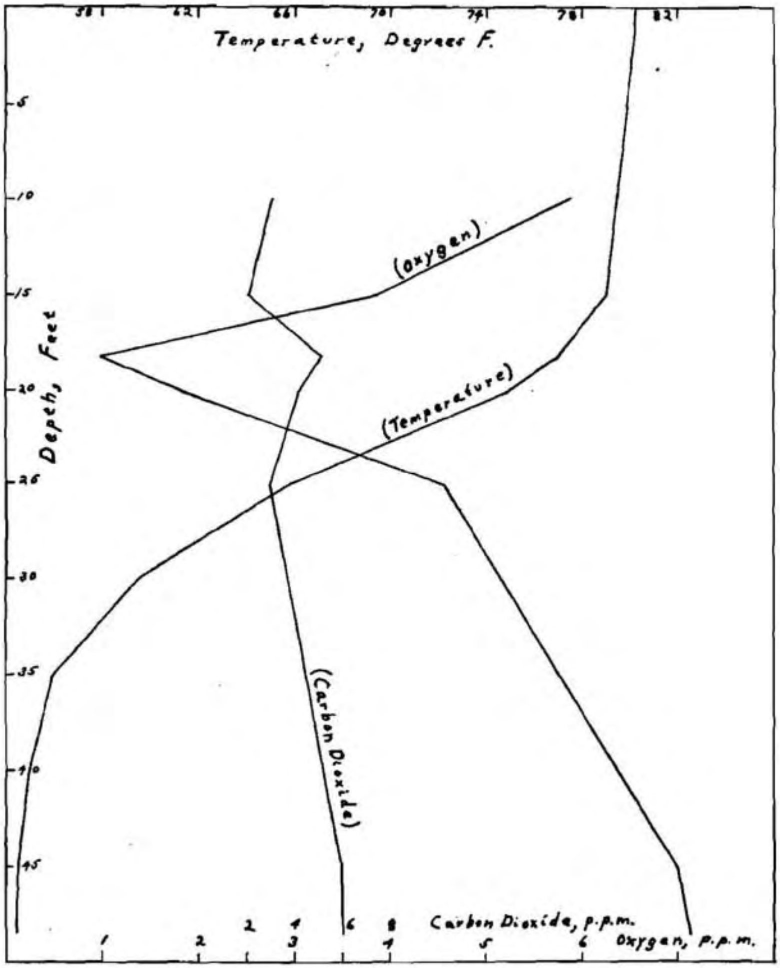
Again, at the six-foot depth, a sample taken in the algae contained 10.8 p. p. m. of hydrogen sulfide; and a sample taken a foot above the algae contained none.

No hydrogen sulfide was present at any depth which was more than a foot above the algae.

CLUB LAKE

1. *Temperature.* This lake is deep; and the water in its lower depths is relatively little warmed by the summer sun, or disturbed by the action of winds or currents. Hence it remains, in summer, much cooler than the water nearer the surface (see Table 2 and Graph 2). The variation in temperature was from 12.4° to 26.8° C., or from 54.3° to 80.3° F.

2. *Dissolved oxygen* varied from 1.0 p. p. m. at eighteen feet, to 7.1 p. p. m. at forty-eight feet (just off the bottom, which at this place was bare). It may be noticed (see Table 2 and Graph 2) that the dissolved oxygen is more plentiful at the upper and again at the lower depths; and is less abundant at about the depth of the beginning of the abrupt drop in temperature (namely, at about eighteen feet). The probable explanation is that the upper water maintains its oxygen from the atmosphere; and the lower water has retained that oxygen which is held at the spring mixing (or, technically, spring turnover). The water at intermediate depths, however, has lost most of the oxygen that it held



GRAPH 2. Temperatures, Dissolved Oxygen, and Free Carbon Dioxide. Club Lake; Santa Rosa, New Mexico. July 24, 1936

in the spring, and has gained little from the air during the summer.

At another place, however, where the depth was about eighteen feet, a sample taken in the algae contained no oxygen; while a sample taken just above the algae contained 4.8 p. p. m. Here decay of the algae probably was taking place.

3. *Carbon dioxide* was 7 p. p. m. or less at every depth tested.

4. *Hydrogen sulfide* was found in only one sample, that taken in the algae at the 18-foot depth. This sample contained 5.6 p. p. m. of hydrogen sulfide.

PROBABLE CAUSE OF DEATH

A reasonable hypothesis concerning the chemical changes which occurred in Park Lake is as follows: Much of the extremely heavy growth of algae covering the entire bottom of the lake began to die and decay.[19] This process of decay used up oxygen from, and put carbon dioxide into, the water, particularly that part of the water which was in immediate contact with the dead algae.

At the same time, the demand of the decaying organic matter for oxygen was so great that some of the dissolved sulfate in the water was actually reduced (changed chemically), yielding sulfides. The action of the carbon dioxide upon these sulfides liberated hydrogen sulfide.[20] (That this process was still going on at the time of the investigation was evidenced by the fact that samples of water taken in the algae contained considerable hydrogen sulfide and carbon dioxide, and no oxygen.)

Thus the water which was very close to the algae not only was totally deficient in oxygen, but also contained the extremely harmful substance, hydrogen sulfide. But at the

19. See Clark and Smith, *op. cit.*, p. 35.

20. Another possible source of some hydrogen sulfide is the decay itself of sulfur-containing plant remains.

same time, the water two or three feet above the algae was probably very little affected.[21]

However, any circumstance, such as a sudden wind, etc., which would cause abrupt mixing of the water in the shallow lake could be very distastrous, for were the accumulated hydrogen sulfide in the bottom to be suddenly disseminated throughout the lake, the fish, which are always sensitive to abrupt chemical changes, would perish.

Such a mixing may have occurred in Park Lake.

SUMMARY AND CONCLUSIONS

1. Santa Rosa Park Lake was examined chemically, following a sudden fish loss. At the time of the examination the water was in fair, though not optimum, chemical condition for warm-water fish. The water very close to the bottom contained hydrogen sulfide, carbon dioxide, and no oxygen; and hence was definitely in a harmful condition.

2. A probable cause of the death of the fish lies in a sudden mixing of this harmful water with the rest of the water in the lake.

3. The conditions just described constitute a *potential source of danger in any other shallow lake of the Southwest.* Even though the sulfate content of a water is low, and thus the water able to furnish little hydrogen sulfide, the deficiency of oxygen and the abundance of carbon dioxide can bring about death. It is easy to understand how the entire contents of a small, shallow lake suddenly may become mixed, and any harmful substance in one portion of the water disseminated throughout the whole body.

Hydrogen sulfide, in particular, is apt to occur in the late summer on the bottom of these Southwestern shallow lakes; for these lakes provide a favorable environment for the production of algae (plenty of light and proper temperature), and most of them have a high sulfate content.

21. Gases diffuse rather slowly through motionless water.

4. As a contrast to the conditions in a shallow lake, the conditions in a deeper lake in the same region have been described. It is true that in such a lake, as well as in a shallow one, hydrogen sulfide may be produced. But it is very difficult for the water in a deeper lake to become suddenly mixed. Thus, although a small portion of the water may become uninhabitable to fish, the larger part of it remains in good condition.