BULLETIN

OF THE

ILLINOIS STATE LABORATORY

OF

NATURAL HISTORY

URBANA, ILLINOIS, U. S. A.

STEPHEN A. FORBES, PH.D., LL.D.,
DIRECTOR

VOL. IX. JUNE, 1913 ARTICLE X.

STUDIES ON THE BIOLOGY OF THE UPPER ILLINOIS RIVER

BY

STEPHEN A. FORBES AND R. E. RICHARDSON, A.M.

ERRATA AND ADDENDA

Page 54, lines 3 and 2 from bottom, and elsewhere in Article III, for *Cassia chamaechrista* read *Cassia chamaecrista*.
Page 62, between lines 4 and 5 from bottom of table insert *Erigeron annuus*.
Page 101, table, after *Croton glandulosus* read var. *septentrionalis;* and for *Equisetum laevigatum* read *Equisetum hyemale* var. *intermedium*.
Page 131, line 3, for *coerulea* read *caerulea*.
Page 138, last line, for *Ziza* read *Zizia*.
Page 141, line 21 from bottom, dele *Diodia teres*.
Page 169, between lines 3 and 4, insert as follows:
Erigeron annuus (L.) Pers. An interstitial in the bunch-grass association in the Hanover area.
Page 177, line 5, for *eastward* read *westward*.
Page 209, line 3 from bottom, for *copalina* read *copallina*.
Page 210, line 13 from bottom, for *Diospyrus* read *Diaspyros*.
Page 211, line 5, for *Foresteria* read *Forestiera*.
Page 256, line 3 of table, for Dr. H. *M*. Pepoon read H. *S*. Pepoon.
Page 278, line 16, the fifth word should be in Roman type.
Page 286, line 6 (second column), page 295, list of secondary species (second column), and page 353, line 8 from bottom, for *hiemalis* or *hiemale* read *hyemale*.
Page 313, line 4 from bottom (first column), for *pedicularis* read *pedicularia*.
Page 315, line 10, second column, for *Apocynum* read *Apocynum*.
Page 323, line 3 from bottom, for *Cyperus* read *Scirpus*.
Page 330, line 14, for *virginianum* read *virginicum*.
Page 336, lines 3 and 2 from bottom, for *virginicum* read *virginianum*.
Page 337, line 2 from bottom, for *philadelphicum* read *philadelphicus*.
Page 339, in first list of invading species, for *Rhus hirta* read *Rhus typhina*.
Page 351, line 4 from bottom, for *xerophtic* read *xerophytic*.
Page 355, above line 6 from bottom, insert *Scirpus heterochaetus* Chase.
Page 356, line 14 from bottom, for *Symlocarpus* read *Symplocarpus*.
Page 360, line 14, for *Pirus* read *Pyrus*.
Page 362, after line 7, insert *Acer saccharinum* L.
Page 363, line 2 from bottom, for *quadiflorum* read *quadriflorum*.
Page 365, line 14, for *thapus* read *thopsus*.
Page 369, last line, for *Tanecetum* read *Tanacetum*.
Page 417, line 1, dele *the*.
Page 497, line 9 from bottom, for *neglible* read *negligible*, and in foot-note, for *Austalt* read *Anstalt*.
Page 498, line 4 from bottom, for *Lockport* read *Chillicothe*.
Page 500, line 13 from bottom, after *up* insert *in*.
Page 501, line 2 from bottom, for *dissolving* read *dissolved*.
Page 504, line 23, for *gryina* read *gyrina;* line 17, for *dentata* read *knickerbockeri*.
Page 506, line 11, for *vernata* read *ternata*.
Page 507, line 3 from bottom, for *Mazon* read *wagon*.
Page 513, line 19, for *Nepa* read *Zaitha;* line 18, and page 517, line 13 from bottom, page 520, line 12 from bottom, and page 532, line 4, read *naid* or *naids* for *naiid* or *naiids*.
Page 517, line 6 from bottom, for *pondweed* read *pickerel-weed*.

Page 519, for first sentence of last paragraph read as follows:

We have no exactly comparable chemical data for July; but analyses for August give percentages of saturation for Morris and Marseilles as follows: 20.4 per cent. at Morris on the 11th and 11 per cent. at Marseilles on the 12th; 16.35 per cent. at Morris on the 22d and 23d and 7.4 per cent. at Marseilles on the 24th and 25th.

Page 521, line 6 from bottom, and page 529, line 9, for *chrysoleucas* read *crysoleucas.*

Page 525, line 22, and page 536, lines 21 and 24, for *Ekmann* read *Ekman.*

Page 532, line 1, for *Ancyclus* read *Ancylus.*

Page 551, line 7, for *00* read *512.*

Page 615, second line above foot-note, for *106* read 94.

Page 616, line 1, for the second *Bündeln* read *Bündel;* line 2, for *Bündeln* read *Bündels;* line 3, for *aussern* read *ausseren;* line 6, for *zwcierlie* read *zweierlei.*

Page 629, line 12, for *kein* read *keinen.*

Page 634, line 9, for *unternommen* read *unternommenen;* and in line 14 from bottom, after *575* insert *13 fig.*

Plate III, Fig. 1, after the word *mixed* in legend insert *consocies of the.*

Plate IX, Fig. 2, dele the legend and read instead: Root-system of *Tephrosia virginiana,* exposed by blowing of the sand.

Plate X, Fig. 2, dele the legend and read instead: A blowout almost stabilized by bunch-grasses, especially *Leptoloma cognatum.*

Plate XXXIX, for *Calamogrostis* read *Calamagrostis.*

Plate LIV, exchange places of cuts, but not the legends.

Plate LXXXV, for *7* read *7c.*

ARTICLE X.—*Studies on the Biology of the Upper Illinois River.*
By STEPHEN A. FORBES AND R. E. RICHARDSON.

The Illinois River is peculiarly characteristic of the State of Illinois, and, next to the prairies, was its leading natural feature. The level richness of the central plateau of the state is reflected in the turbid waters and the broad sluggish current of the stream; and its wide bottom-lands, originally covered with huge trees, completely flooded when the river is highest, and holding many marshes and shallow lakes at its lowest stages, are a relic of the time, not so very far remote, when the limpid waters of the Great Lakes rolled down its valley in a mighty flood on their course to the southern gulf. It was not an accident that this river was the first great artery of transportation into and through the state, or that the first colonial settlement and the first fortified post in Illinois were established on its banks. After the railroads had deprived it of its commerce it was discredited and neglected for many years, and the second city in the country and the second city of the state have long used it as a mere convenience for the discharge of their organic wastes.

These are temporary conditions, however, and the time seems now at hand when the people of Illinois will learn to appreciate and develop this great gift of nature in the various directions in which it may be made to serve their interests and their pleasures. Its frequently beautiful and occasionally picturesque scenery is attracting more attention every year; and when, as is sure to happen in due time, a superior highway follows its course between Chicago and St. Louis; when the attractive building sites on its banks are relieved, as they now might generally be, from the midsummer plague of mosquitoes; when its most interesting situations are converted into public parks, and its fisheries are protected and enriched by means of state reservations for the breeding and feeding of fishes; and when, as must eventually come to pass, it becomes once more an indispensable central link in a principal line of traffic between the Great Lakes and the Gulf,—it will take for all time, for the state at large, the place which Lake Michigan now holds for our greatest city.

The senior author of this report began work, as a biologist, on Illinois River problems, some thirty-six years ago; and the junior author has virtually lived on the river for purposes of investigation during the last four years. The Natural History Survey of the state

has published in the meantime more than twenty-five hundred pages of contributions to its biology; and it is now rounding this work to a close, and bringing its results to bear, in practical ways, upon the economic problems most pressing and important at the present time. The paper here presented is intended as a preliminary summary only of the principal conclusions, scientific and economic, to be drawn from our studies of the last few years, and it is to be followed presently by a series of special papers on the various divisions of the investigation.

Acknowledgments

Our grateful acknowledgments are due to the U. S. Bureau of Fisheries for financial assistance in carrying out a fairly adequate program of field work in 1911 and 1912; to the Illinois State Fish Commission for opportunities afforded us to obtain the plankton of the Illinois, Mississippi, and Ohio rivers on long steamer trips which we could not otherwise have made; to the Water Survey of the State, the director of which, Dr. Edward Bartow, has taken virtual charge of the chemical work here reported, and has provided, from his staff, experienced analysts who have made all our determinations of gases from the waters and from the river sediments; and to the directors of the Missouri Botanical Garden, in St. Louis, Dr. Wm. Trelease, succeeded by Dr. George T. Moore, who have placed the library, collections, and laboratory facilities of the garden at our disposal, and the latter of whom has given us also his personal assistance in determining the algæ of our river collections.

Objects of the Investigation

The Illinois River work of the Natural History Survey, pursued at irregular intervals since 1877, became virtually continuous at Havana for five years, from April, 1894, to March, 1899, after which it seemed expedient, first to diminish, and in 1903 to suspend, field operations in order that our more important scientific results might be organized, reported, and published. This end being largely accomplished by voluminous papers printed in volumes IV, V, VI, and VIII of the Bulletin of the State Laboratory of Natural History, and by the publication also, in 1908, of an elaborate report on the fishes of the state, active field work on the river problems was resumed in July, 1909.

The opening of the Chicago Drainage Canal in 1900 was a revolutionary event in the biological history of the river; and as the

most important period of our earlier work was that immediately preceding this event, an examination of its consequences to the general system of aquatic plant and animal life was an important part of our object in recommencing systematic study. As the Illinois is a rather peculiar member of the great Mississippi River system, it was also much to be desired that comparative studies should be made on the life of the more closely related companion streams; and as the Illinois is economically one of the most productive rivers in the United States, it was evidently time to study the subject of the conservation and possible increase of its values in the light of the knowledge we had gained, and intended to gain, of its physical, chemical, and biological conditions and requirements.

The economic problem seemed especially urgent because of the great changes in progress at the time in the environment of the river, and the still greater changes impending, which were certain to affect greatly and permanently its value for the purposes which it had previously served. Reclamation projects, for the protection, drainage, and cultivation of its bottom-lands; manufacturing projects, threatening various contaminations of its waters; canalization project; and projects for the control of its flow in the interests of transportation, were all being earnestly agitated, and some of them were in course of active development. It is true that these changes are both inevitable and desirable, in view of all the interests involved; but it becomes all the more imperative to learn as promptly as possible what their effects have been and are likely to be, in order that practical correctives may be applied where necessary, to the end that a *modus vivendi* may be found which will take all these interests into full account, and make sure that nothing is needlessly sacrificed in the course of the use and development of the stream.

The reports of the work of the earlier period were largely on the minute plant and animal life of the stream—its so-called plankton—which forms a considerable part of the food of many kinds of fishes and nearly all the food of the young of almost every kind; and the plankton product of the waters of the Illinois under the new conditions, as compared with those prevailing before the opening of the sanitary canal, was one of the first topics to commend itself to us for careful study. Involved in this subject of food production for fishes, river mussels, and other useful aquatic animals, was the economic effect of a great increase in the flow of the stream, the rise in its levels, and the consequent expansion and longer continuance of its overflows, which there was some reason to suppose might so increase the food supply and enlarge the breeding and feeding grounds

of fishes as to increase the fisheries products of the stream. It was also a matter of interest and importance to learn the effects, both direct and indirect, of the increased inflow of sewage by way of the sanitary canal and the Des Plaines, upon the fishes and mollusks of the Illinois—an inquiry calling for chemical examinations of the waters of the stream and systematic collections from it at various points on its course, under various conditions, and at different times of the year.

Character and Chronology of Field Operations

The work planned upon these lines has taken three directions: the first year was given mainly to a study of the plankton of the river and of the principal bottom-land lakes, made on the same grounds and by the same methods and equipment as those of the period from 1894-1899; the second year was devoted especially to chemical determinations of the gases of the waters and of the bottom sediments of the upper river, from its origin to Chillicothe, and to parallel collections of the minuter plankton—the so-called microplankton—of the stream made at the same times and places as the chemical studies; and in the third year, similar chemical and biological determinations were made, with principal attention, however, to fishes and mussels and to the other plant and animal life of the bottom and the shores.

Advantage has also been taken of opportunities given us by the State Fish Commission to collect the plankton of the Mississippi and Ohio rivers for comparison with that of the Illinois, and especially to study the effect of protracted drouth and continuous low water on plankton production in the streams themselves. Much time was given during the spring seasons of 1910 and 1911 to field studies of the habits of spawning fishes and the times and places where their eggs were laid, and to the fate of the eggs and the rate of growth of the fry. These observations were intended especially to give us a better knowledge of the proper limits of a closed season for the protection of the more valuable fishes, and to show us also what measures are necessary to keep the numbers of the young up to the limits set by the available food supply.*

The collection of materials for a comparative study of the plankton of our principal rivers was actually begun in 1902, when virtually continuous collections were made from the steamer "Illinois" of the

*For a summary of results, see Bull. Ill. State Lab. Nat. Hist., Vol. IX, articles VII and VIII, March, 1913.

State Fish Commission, beginning at Montezuma, on the lower Illinois River, going thence to Grafton, at its mouth, from Grafton up the Mississippi to Quincy, down that stream to St. Louis, from St. Louis back to Grafton, and thence up the Illinois to Pekin. The systematic plankton collections of this trip were the first ever made on the Mississippi River. Additional collections were obtained in 1902, by the use of the station launch, from Pekin to Peoria Narrows, and in August, 1903, from Wesley, below Peoria, to Henry, thirty-three miles above. The next long trip was made June 8-17, 1910, again on the steamer "Illinois," from Keokuk, Iowa, to Quincy and St. Louis, and thence up the Mississippi and the Illinois to La Salle, with a return to Havana; and additional materials for a study of the plankton were obtained by means of numerous collections in Peoria Lake, July 19-22 of this year. The final trip of the series was made with the "Illinois" July 25 to August 6, from Havana down the Illinois and the Mississippi to Cairo, and thence up the Ohio to Paducah, Ky., where we left the steamer, to rejoin it at St. Louis for continuous collections up the Mississippi and the Illinois to La Salle, and back to Havana.

In 1911, chemical determinations and biological collections for an analysis of seasonal conditions on the upper Illinois and in related waters, were begun July 18 and repeated at frequent intervals until the 13th of December. Similar trips were made in February and March, 1912, for a study of winter conditions; and in July, 1912, an elaborate series of oxygen determinations was made for the entire length of the river. August 21 to October 12, two such series were obtained for the upper Illinois; and in November two more, for the whole stream, with comparative tests for the Mississippi, below and above the mouth of the Illinois. The situations thus brought more or less closely into comparison were the sanitary canal at Lockport, the Des Plaines River at the same place and at its mouth (Dresden Heights), the Kankakee just above its mouth, and the Illinois River at Dresden Heights, Morris, Marseilles (both above and below the dam which crosses the river there), Ottawa, Starved Rock, Peru, Hennepin, and Chillicothe. The distances of these points from the mouth of the Chicago River are approximately as follows, in miles: Lockport, 35; Dresden Heights, 53; Morris, 62; Marseilles, 80; Ottawa, 86; Starved Rock, 95; Peru, 102; Hennepin, 116; and Chillicothe, 145, ninety-two miles of this last-mentioned distance being on the Illinois River itself.

In 1911, low-water midsummer conditions were shown by studies pursued between July 15 and August 29, during which time three

successive trips were made, the first from Lake Michigan and Lockport to Chillicothe, and the other two from Dresden Heights to the last-named point. Early autumnal conditions were studied from Lockport to Chillicothe at various dates in September; late autumnal conditions between the same points, November 1-10; and winter conditions at Morris and Marseilles, November 30 to December 3.

On this last visit the collection of fishes from the more contaminated parts of the stream was first attempted by means of seines. Observations on fishes had, however, been made at various points from the beginning of operations in July.

From the 16th to the 28th of February, 1912, efforts were persistently repeated at Morris to obtain fishes from the river by the use of seines and fyke-nets, and by the explosion of dynamite. Oxygen determinations were secured at this time from all the usual points between Lockport and Chillicothe, as well as from the Kankakee above Dresden Heights; and the following month (March 18-28) a full series of such determinations was made the whole length of the river from Morris to Grafton, from the Des Plaines and the sanitary canal at Lockport, and from the Mississippi above the mouth of the Illinois. It was the object of this series to give us the data for a comparison of extreme seasonal conditions throughout the course of the stream.

Lack of funds prevented a resumption of our biological river work in the spring of 1912; but the new appropriations of the Natural History Survey, available July 1, fortified by an allowance from the U. S. Bureau of Fisheries, enabled us to resume the collection of chemical and biological data August 1, and to continue it without intermission until October 25.

In this time the chemistry and biology of the situation was studied, on two successive trips, at each point from Lockport to Chillicothe, collections of plants and animals being obtained with dip-nets, large and small seines, trammel-nets, set-nets, dredges, and the mussel-bar, and by the explosion of half-pound cartridges of dynamite, and oxygen ratios being determined for each place and time at which the biological data were obtained.

Finally, in March, 1913, samples of the bottom sediments were collected from all the five Illinois River dams, and from some other points in the main channel, for physical and chemical examination, with a view to ascertaining the condition of the river bottom when the river water has been for some months at or near the freezing point.

Importance of the Plankton

The economic importance of the plankton is largely in the predominance of these minute animals and plants in the food of the young of our most important fishes,—a predominance which may be expressed, without serious exaggeration, in the aphorism: no plankton, no fish. Furthermore, adults of many useful species, the crappies and the sunfishes, for example, often cram their stomachs with plankton organisms when these are especially abundant, as in spring. The youngest fishes and adults differ, however, as a rule, in their mode of obtaining this kind of food, the latter straining it out of the water by means of their gill-rakers and the former capturing the minute animals one by one, as full-grown predaceous fishes capture their larger prey. There is, indeed, an important exception to be made to the foregoing too sweeping statement. The young of the sucker family seem to take their earliest food much as do the adults—by sucking it up from the bottom—and while many plankton organisms are caught by them in this way, these are largely forms which commonly live on or near the bottom, the free-swimming species (*Daphnia, Cyclops,* and the like) being commonly scarce in the food of this family. The young of some other species also feed habitually near the bottom, so that the bottom-loving plankton organisms are represented in their food in disproportionate numbers as compared with the average product of the plankton net. Nevertheless, conditions which bring about an abundance of true-floating or free-swimming plankton, have, generally speaking, a like effect on the more significant part of the minute bottom-life of our waters generally, and the yield of the collector's net is thus a fairly reliable index to the food supply of young fishes, of whatever habit. It is true that these, as a rule, make little use of the plants of the plankton as compared with its animals, and that the numbers of the two often do not vary together; but if we remember that the plankton animals themselves feed largely on microscopic plants, we shall see that the latter are indirectly useful to fishes, even when not directly so.

Changes in River Levels

It follows from the foregoing discussion that one of the important points to be determined in our earlier operations of 1909 and 1910 was the effect on the plankton content of the Illinois River and its connected waters traceable to the opening of the Chicago

Drainage Canal, and to the increase in the volume of the stream and in the extent and continuance of its overflow consequent upon that event.

Something of the magnitude of this increase may be inferred from a comparison of the river-gage readings at Havana or below Copperas Creek dam for two ten-year periods preceding the opening of the canal (on January 17, 1900) and the ten years immediately following. The period from 1880-1889 inclusive was characterized by relatively high water, with an average of 7.4 feet above the low-water base-line of 1879; the second, from 1890-1899, was a low-water period, with an average gage reading of 6.32 feet; and the third or last period of ten years, from 1900-1909, was a maximum period, with an average of 9.72 feet. Taking these last two periods into comparison, separated, as they are, by the opening of the sanitary canal, we find a difference of 3.4 feet of average level, attributable in great part to the access of canal waters. There was, however, an apparent difference between these two periods in the rainfall of the upper Illinois basin amounting to 1.9 inches, which may be held to account for a part of the average high water of the later one.

The River Plankton

Our Havana plankton collections were made in series, at sufficiently frequent intervals between August 30, 1909, and August 29, 1910, from three localities—the Illinois River, Thompson's Lake, and Quiver Lake. Forty collections were made in this period from the river, forty from Quiver Lake, and thirty-nine from Thompson's, distributed as follows by months: 1909—August, 1 collection; September, 4 collections; October, 4; November, 5; December, 2. 1910—January, 1; February, 1; March, 2; April, 4; May, 4; June, 3; July, 5; August, 4. In December only one collection was made from Thompson's Lake.

The average plankton product of the Illinois River for each month of this year (August, 1909, to August, 1910), stated in cubic centimeters of plankton to one cubic meter of water,* is shown in the following table, together with corresponding monthly averages for the three years from September, 1895, to August, 1898, inclusive.

*Equivalent, of course, to parts per million *by volume*.

ILLINOIS RIVER PLANKTON, MAIN STREAM AT HAVANA, ILL., 1895-'98 AND 1909-'10. GIVEN IN CUBIC CENTIMETERS OF PLANKTON TO ONE CUBIC METER OF WATER

	'95-'96	'96-'97	'97-'98	'09-'10
September	1.52	.38	6.33	.10
October	.57	1.10	5.94	2.58
November	3.02	.02	1.	1.38
December	1.19	.76	.56	.38
January	.01		.45	.01
February	.01	.04	.27	.21
March	.07	.38	.33	2.18
April	5.69	5.11	4.40	29.60
May	1.30	5.62	11.30	12.27
June	.71	.27	3.96	11.89
July	1.44	4.78	.58	.23
August	1.17	3.65	.91	.06
Averages	1.39	2.10	3.	5.07

These are the only years of the earlier collecting period for which our data are sufficiently continuous to serve the purpose of a comparison. The general average of monthly averages for the year 1909-'10, it will be seen, was 5.07 cm., those for the earlier years being, respectively, 1.39, 2.10, and 3.

From a scrutiny of the columns of figures of these three years in comparison with the column for 1909-'10, it becomes evident that the series of monthly plankton products for 1897-'98 has much the closest resemblance to that of 1909-'10, and that this is the year that must be chosen for our comparison, so far as the data of average plankton production are concerned.

If the figures of the following table of gage readings be compared in the same manner and for the same purpose, it will be seen that the series for 1897-'98 resembles 1909-'10 more closely than any one of the four years of the earlier period of this table, the principal difference being in the autumnal months, when plankton production is relatively small at best and is of comparatively little significance as an item of fish food.

MONTHLY MEANS OF GAGE READINGS
ILLINOIS RIVER, HAVANA

	'96-'97	'97-'98	'98-'99	'99-'00	'09-'10
September	4.62	2.01	4.44	2.63	8.01
October	6.04	2.01	4.26	2.99	7.37
November	5.89	2.82	7.44	3.88	8.94
December	5.48	3.22	6.59	4.74	11.45
January	11.28	5.08	7.99	5.83	6.98
February	11.13	8.94	7.02	9.39	8.71
March	13.89	12.99	13.05	14.33	12.63
April	13.40	14.	11.15	13.44	12.28
May	9.41	11.55	8.02	9.52	13.98
June	5.54	11.53	7.80	7.61	12.14
July	6.05	5.70	4.38	5.94	11.02
August	2.29	3.66	3.20	6.36	8.76
Averages	7.92	6.96	7.11	7.22	10.19

We have thus two reasons for making the year 1897-98 the basis of our comparison of plankton production before and after the opening of the drainage canal; and as that for the former year is 3 centimeters per cubic meter and for the latter is 5.07 centimeters, we have sufficient reason for concluding that the plankton production of the stream has been largely increased per unit of volume as a consequence of the opening of the drainage canal, and that, so far as the evidence goes, the ratio of the present yield to the former is at least as 5 to 3.

Remembering further that the most important plankton product is that of the spring months, when young fishes are hatching from the egg and are dependent upon the plankton organisms for their earliest growth as fry, we find a special significance in the fact that the plankton yield of the river for the months of March, April, May, and June, was 2.85 times as great in 1910 as it was in 1898; or, if we omit the month of June as rather late for this purpose, the yield of the former year, March to May, is still 2.12 times that of the latter year. Taking for our comparison all the plankton averages for March, April, and May in all the years from 1894 to 1899, we find that the yield of these months in 1910, averages 4.29 times that of the same months of the earlier period.

From these various points of view, therefore, we are compelled to infer a much larger plankton yield to the cubic meter of water in the Illinois River itself at Havana during the year September,

1909, to September, 1910, than in any year of our collection period preceding the opening of the drainage canal. As the river contains, generally speaking, a mixture of contributions from all its tributary waters, the quantities of its plankton, particularly during the spring months when these waters communicate with it most freely, are the best obtainable index to plankton production in the whole system of streams and lakes whose surplus water it carries away. Nevertheless, a comparative study of conditions in two highly typical bottom-land lakes, so made as to show the effects in them of a change to the new and higher water-level, will have its special interest, particularly as it is in these bottom-land backwaters that most of the fish fry are hatched, and spend, as a rule, the first weeks of their existence.

The Lake Plankton

Thompson's Lake.—Thompson's Lake is a typical, permanent bottom-land lake, continuously connected with the river at all stages of water. In the higher stages the land between it and the main stream is completely overflowed; at medium stages the river water enters at its upper end and flows out from its lower; but at the lowest levels the lake is connected with the stream only by a narrow creek-like outlet at its upper end. At six feet above "low water" it covers nearly 3000 acres; and at a river level of nine feet its area is about 4300 acres.*

As will be seen from the following table, the plankton series of Thompson's Lake for 1909-10 does not closely resemble any one of the series of the earlier years, although the latter part of it, from February to August, 1910, is quite similar to the corresponding part of the record for 1897-98.

*Tabulation of Areas of Thompson Lake for the Various Water Elevations. Report of the Submerged and Shore Lands Legislative Investigating Committee (Forty-seventh General Assembly), Vol. I, p. 171.

PLANKTON OF THOMPSON'S LAKE, 1894-99 AND 1909-10
CUBIC CENTIMETERS TO THE CUBIC METER

	'94-'95	'95-'96	'96-'97	'97-'98	'98-'99	'09-'10
September	6.40	3.58	4.19	10.	2.65	3.34
October		3.15	2.81	35.35	1.24	3.54
November		5.07	2.66	16.67	1.17	8.25
December	1.29	1.	2.56	5.95	3.58	13.04
January		2.51		.46	2.46	2.28
February		2.58	.27	.24	1.58	.70
March		10.26	.65	.05	.21	.44
April	28.20	16.97	10.38	2.80		2.93
May	61.44	23.11	7.88	25.94		31.56
June	9.42	24.92	3.59	10.43		16.24
July	4.82	10.74	3.31	2.08		4.88
August	3.09	1.08	19.40	2.63		6.07
Averages		8.75	5.25	9.39		7.77

Averages for March, April, and May:
1895–96 to 1897–98 10.89
1909–10 11.68

Comparing the two years for these three months only, we find the plankton average for 1897-98 to be 6.31 cubic centimeters, and that for 1909-10 to be 8.97 cubic centimeters. If, however, we compare the average for these two years entire, the yield for the former year is 9.39 and that for the latter is 7.77. If, on the other hand, we take for comparison the plankton yields for March, April, and May of all three years, from September, 1895, to August, 1898, inclusive, we find these to average 10.89 cubic centimeters as compared with 11.68 for the year 1909-10. It would appear, consequently, that there is no notable change to be made out in the productivity of the waters of the lake per unit of volume, as compared with the period preceding the opening of the drainage canal. It is to be noted, however, that the very much greater average area of this lake under present conditions, and the much larger, freer, and more continuous contributions to the river made by it at the higher levels must, of course, be taken into account in any discussion of the causes of the much richer plankton of the river itself.

Quiver Lake.—Quiver Lake, at stages low enough to separate it from the main stream, is a mere broad bay of the Illinois, opening widely at its lower end, receiving the waters of Quiver Creek above, and fed in part by many springs along its high, steep, and sandy eastern bank. It was formerly clogged with vegetation in midsum-

mer and in fall, except when occasional floods would sweep it clean for a time; but since the drainage canal was opened its character is completely changed, and there is now but little vegetable growth to be seen in it at any time of the year. It is also, of course, now considerably larger and much more freely connected with the river than before, and the lowlands separating it from the stream are much longer under water.

PLANKTON OF QUIVER LAKE, 1895-99 AND 1909-10
CUBIC CENTIMETERS TO THE CUBIC METER

	'95-'96	'96-'97	'97-'98	'09-'10
September	.94	.31	.16	1.16
October	.13	2.10	.04	.65
November	.05	.24	.09	7.16
December	.46	.91	.006	1.20
January	.03		.021	1.17
February	1.75	.19	.30	.60
March	1.85	.34	.74	3.18
April	12.12	13.38	.53	38.26
May	2.99	1.29	16.24	13.
June	1.26	1.26	2.22	3.14
July	.29	.89	.16	1.04
August	2.46	.20	1.66	2.80
Averages	2.03	1.92	1.85	6.13

Averages for March, April, and May:
1895-'96 to 1897-'98 5.50
1909-'10 16.15

Consistently with these facts its plankton content per cubic meter is very much greater than formerly, in whatever way the ratios may be figured. Its average for the year 1909-10 is 6.13 centimeters per cubic meter, while the highest average of any one of the three earlier years was 2.03, and the general average for the three years was 1.93. The present yield is thus more than five times that of the former period. If we take into account the spring months only (March, April, and May), the average yield for the three earlier years was 5.5 centimeters, and for 1909-10 it is 16.15—virtually a threefold increase at this most important season.

RIVER AND LAKES COMPARED

That a great change has been produced in the relative productivity of the river and the lakes is evident from the following table of the average yield of plankton per cubic meter of these three waters.

	River	Quiver Lake	Thompson's Lake
1895 & '96 to 1897 & '98	2.16	1.93	7.80
1909 & '10	5.07	6.13	7.77

In the three full years of the earlier period whose data are used in this discussion, the plankton of Quiver Lake water was lowest, that of the river was but little higher, and that of Thompson's Lake was three and a half times the latter. In 1909-10 the yield of the river was lowest, that of Quiver Lake was 21 per cent. larger, and Thompson's Lake yielded 27 per cent. more than Quiver, the change being due to a great increase in the river yield and a still greater increase in that of Quiver Lake, while the yield of Thompson's Lake remained substantially unchanged.

If to these facts concerning the increase, in recent years, in the percentage of plankton contained in the waters of the Illinois, we add those concerning an increase in the average volume and area of the waters themselves, we shall see that their total plankton product must have been many times multiplied, and that the fisheries of the stream should feel the effects of this greater abundance of this important element of fish food; provided, it must be added, that the plankton supply is really at any time a limiting element in the production of fishes, such that we may amend the aphorism given on another page, to the form: "The more plankton, the more fish." It will, however, be a long time, in the writers' judgment, before the whole economy of fish production in our streams is so thoroughly understood that such a statement will be warranted. At present we can only say that there was produced in the waters and backwaters of the Illinois, in 1909-1910, an available and accessible amount of fish food sufficient for a much greater population of fishes than the stream had previously supported, and that if no such population is maintained, the reasons for the fact must be sought in some other direction.

Causes of an Increased Plankton

No change has recently occurred in the Illinois River system, or in the basin of the Illinois, to account for the increased productivity of its waters except the one already repeatedly referred to—the opening of the sanitary canal connecting the Illinois and the Chicago rivers at the beginning of 1900. The effects of this occurrence on the plant and animal products of the stream may conceivably have been produced in one or more of these three principal methods: (*a*)

by a mere increase of the waters themselves, which, in so sluggish a stream as the Illinois, with bottom-lands so extensive and so widely overflowed by so small a rise of the river levels, will take effect mainly in great expansions of shallow water, long continued or permanently maintained, with muddy bottoms and more or less weedy shores—situations quite capable of producing a relatively enormous plankton as well as an abundant supply of shore and bottom animals and plants; (*b*) by the addition of increased quantities of organic matter to the contents of the stream in the form of a larger inflow of sewage from Chicago and its suburbs, in condition to increase the plankton by increasing the supply of food available to the minute organisms which compose it; and (*c*) by the addition to the plankton of the river, of that of Lake Michigan brought down in the waters of the canal.

The efficacy of the first of these conditions is undoubted, as has been already shown, and that of the second is, generally speaking, quite possible. The importance of an abundance of organic matter in the water as a means of producing a rich plankton is, in fact, so well known that growers of pond fishes in Europe deliberately manure their ponds to increase the supply of food for their fish; and there is considerable evidence, also, that the plankton of the Elbe is largely increased by the sewage of Hamburg and Altona poured directly into that stream. Whether Chicago sewage has a like effect in the Illinois, and whether, if it has, that effect may not have disappeared before the waters of the stream have reached Havana, are problems which will be taken up in a later paper. The supposition that the waters of the canal may bring to the Illinois a richer plankton than that of the river itself is negatived at once by the fact that Lake Michigan water is relatively poor in microscopic life, and hence must dilute the river plankton instead of increasing it; and by the further fact that most of the characteristic minute organisms of the lake have died out in the river before they reach Havana.*

ILLINOIS RIVER WORK OF 1911 AND 1912

The Illinois River, it will be remembered, is formed by a union, near Dresden Heights, of the uncontaminated Kankakee and the heavily polluted Des Plaines. The waters of these streams flow down

*A partial exception to this statement is found in the survival in the river of the lake diatom *Tabellaria flocculosa*, its increase after it passes the Morris-Marseilles ordeal, and its immense multiplication in Peoria Lake. This species was not found in the Illinois before the opening of the drainage canal.

the larger river, the Des Plaines water on the north side and that of the Kankakee on the south, and are not completely mingled until the first dam is reached, at Marseilles, twenty-six miles below. They are less distinct, however, than they would be if it were not for an unfinished dam at Dresden Heights, which acts as a wing-dam to concentrate and hasten the current of the Des Plaines, throwing it with some force towards the other side of the Illinois, thus artificially mixing, to some extent, the waters of the Kankakee and the Des Plaines at their junction. These continue sufficiently separate, however, as far down as Morris, nine miles below the junction, to make a notable difference in contamination between the two sides of the stream.

The effect of the dam at Marseilles is to check the current above sufficiently to permit a considerable precipitation of suspended matter, which accumulates there in a deep bed of more or less putrid sludge. In going over the dam the water is thoroughly mixed and aerated, and the softer masses suspended in it are pulverized, and thus made ready for more rapid decomposition.

Between Dresden Heights and Morris the waters of the Illinois are slightly diluted by contributions from the Au Sable on the north and Mazon Creek on the south. At Ottawa, the Fox River comes in from the north—a stream a hundred and fifty miles long with an estimated low-water discharge of about two hundred and forty cubic feet per second.* On the southern side is the Vermilion, ninety miles long, emptying opposite La Salle.

These are the only tributaries of the upper river of sufficient importance to be noticed as influencing sensibly chemical or biological conditions in the main stream. A cluster of bottom-land lakes of some importance is found above Hennepin, and Senachewine Lake has its outlet into the river between that town and Henry. At the latter point is a dam which repeats, to some extent, the effects of the upper dam, at Marseilles. Chillicothe, which was the lower limit of most of our operations, is at the upper end of that expansion of the Illinois known as Peoria Lake.

The Microplankton, Summer of 1911

Three successive rounds were made in the summer of 1911 to the selected list of stations between Dresden Heights and Chillicothe, by a chemist (Mr. Charles H. Spaulding) and a biologist (the junior

*Chemical and Biological Survey of the Waters of Illinois, Report for 1911, p. 162.

author) working conjointly. The first trip was made July 18 to August 4; the second, August 10-17; and the third, August 21-29.

The weather of July and August, 1911, was unusually dry and hot, with the river continuously at very low level. A rain of about a quarter of an inch fell July 20, in the upper Illinois valley, but this had no perceptible effect on the river. Upwards of an inch of rainfall August 10, followed by a rise of about six inches in the Kankakee, also brought the Illinois up in the Morris-Marseilles section, and the August stage of water was throughout a little higher than that of July.

In collecting from the waters of the flowing stream, all samples were taken within eighteen inches of the surface, by means of a liter-bottle opening and closing mechanically. On the return from the field the contents of each liter flask were thoroughly shaken together and 50 cubic centimeters were drawn off with a pipette and reduced to 10 centimeters by straining through No. 575 S. & S. hard-pressed filter-paper. After this condensed sample was thoroughly shaken, a Rafter cell holding one cubic centimeter was filled, and counts of the *living* plankton were made under a microscope by the methods usually employed in preserved specimens. The above method of collection is a slight modification of that recently used by Kolkwitz,* differing from it chiefly in the fact that the samples were condensed before examination. The fundamental feature is the direct field examination and enumeration of the living organisms in small samples, which in the practice of Kolkwitz were not strained or condensed in any manner.

This concentration process seemed to us to be called for to insure a number of organisms in the samples examined, sufficient to give a dependable count. The correctness of the method used is, in our opinion, fairly attested by the general consistency and reasonableness of the figures obtained, if proper account is taken of the known variability of hydrographic and chemical factors. A few special tests of it were nevertheless made. (*a*) Duplicate counts of collections from the same place on the same day showed neglible differences only. (*b*) A collection obtained at Chillicothe August 17, containing a total of 162 organisms per cubic centimeter (not counting bacteria,) was filtered, and a centimeter of the filtrate was found to contain no organisms except a few bacteria. (*c*) A collection from Depue Lake containing 40,000 chlamydomonads per centimeter was filtered, and the filtrate contained only 147 green monads

*Mitth. aus der Kgl. Preuss.-Anstalt für Wasserversorg. und Abwasserbeseitigung zu Berlin, 1907.

per centimeter, a residue of .3 of one per cent. which had escaped through the filter-paper. (*d*) A Fox River collection made September 2, containing 3161 organisms per cubic centimeter, yielded in the filtrate 12.6 organisms per centimeter, less than .4 of one per cent.

There was, of course, always some undeterminable loss through adhesion to the filter-paper, but this was minimized by the large amount filtered (50 cubic centimeters), and by thorough washing of the filter during the removal of the 10-centimeter residue. To all appearance the loss was very slight, and, the error being practically uniform since the same methods were used throughout, it could not invalidate comparisons.

Definition of Terms.—As a considerable part of this paper will be given to a description of the criteria and effects of different degrees of contamination of the natural waters of the Illinois, we will distinguish, as clearly as convenient, three stages of impurity, by the use of the following terms applicable both to the waters themselves and to the characteristic organisms, given here in the order of a diminishing impurity, namely, (1) septic or saprobic, (2) polluted or pollutional, and (3) contaminated or contaminate; and to these we will add "clean water" to indicate the conditions and organisms substantially equivalent to those of the natural, uncontaminated stream. These expressions seem sufficiently definite and significant to distinguish between stages which at best can not be sharply marked off; and we prefer them for our purposes to the equivalent highly technical terms polysaprobic, mesosaprobic α, mesosaprobic β, and oligosaprobic, introduced by Kolkwitz and Marsson.

Only a very general account of the product of these collections will be given at this time, the subject being reserved for more detailed report in a later paper.

For a merely general and preliminary presentation of our data of 1911 relating to the midsummer microplankton of the upper Illinois, we may conveniently divide the waters from which our collections were made into four sections or general situations, corresponding to distinguishable stages of pollution and self-purification; (1) the sanitary canal at Lockport, (2) the Des Plaines River at Dresden Heights and the Illinois River from that point to Marseilles, and (3) the Illinois River from Marseilles to Starved Rock, and (4) from Starved Rock to Lockport.

In the sanitary canal at Lockport we found, in September, 1911, an abundant Lake Michigan plankton with little admixture of septic organisms. It was largely composed of characteristic lake diatoms

and flagellate *Protozoa* of the *Chlamydomonas* type, still living and in process of multiplication,— a fact easily understood, in view of the recent origin of the water in the lake and its undisturbed flow and relatively low temperature in the deep canal.

The Des Plaines River at this point was heavily loaded with sewage wastes derived partly from the sanitary canal, which sends into it an overflow through the turbine waste ditch of the controlling works, and at times also through the sluice and over the bear-trap dam at the same point. This stream was heavily contaminated also, in 1911, by sewage from several suburbs of Chicago on the Des Plaines above Lockport. As it was very low and the water spread in a thin sheet over a rocky bottom, its temperature was much higher than that of the canal, and septic organisms were at their maximum. The most conspicuous of these was the well-known "fungo-bacterium," *Sphærotilus natans,* a filamentous form which grows in long, loose, hanging tufts and branches in septic and polluted waters. The stony bottom of the Des Plaines between Lockport and Dresden Heights was carpeted with this plant, and with it were associated a considerable variety of *Protozoa* (*Carchesium lachmanni, Vorticella microstoma, Epistylis plicatilis, Oikomonas termo, Bodo saltans,* and *Paramecium putrinum,*) all characteristic foul-water species. These were continually being torn loose by the swift current of the lower Des Plaines and mixed with the free plankton, with which they were carried far down the stream, feeding and multiplying as they went, until a gradual purification of the water made it unfit for their maintenance.

The Illinois from Dresden Heights to Marseilles was, in July to September, 1911, an especially saprobic or septic section of the river, this condition culminating at Morris, if we may judge by the numbers of septic organisms in the plankton. The most abundant of these were *Sphærotilus natans,* detached filaments of which made about 90 per cent. of the number of the plankton organisms in this and the following section. These were most abundant at Dresden Heights, and were much more so at Morris than at any point below. Several of the larger species of saprobic bacteria, not essentially different in food requirements from *Sphærotilus natans,* were notably abundant in this section: *Bacterium vulgare, Spirillum volutans,* and species of *Streptococcus* were common examples. The largest collections of detached heads of the *Vorticellidæ* (*Carchesium lachmanni* and *Epistylis plicatilis*) were made at Dresden Heights and Morris. Flagellate, colorless *Protozoa* which feed upon bacteria, were also extremely abundant in this section. The largest numbers of *Oiko-*

monas termo were found at Marseilles above the dam, and the number at Morris and below the dam at Marseilles was much larger than at stations either above the former or below the latter point. It was further characteristic of this section that one-celled green algæ and green flagellate *Protozoa* were nearly absent in its waters except for survivors of the Lake Michigan contribution. Even the hardier Lake Michigan diatoms were distinctly waning in numbers, their moribund condition being plainly shown by the fading and breaking down of their chloroplasts. On the other hand, many diatoms come through this section alive, particularly the two species of *Tabellaria* (*fenestrata* and *flocculosa*) together with some of the Synedras and Naviculas.

The microplankton collections of the section from Marseilles to Starved Rock agree with the longshore collections to the effect that the septic organisms were diminishing rapidly here, *Sphærotilus* and *Carchesium* disappearing from both the waters and margins, but appearing in dredgings from the bottom of the channel, to which these organisms had seemingly settled to die. *Oikomonas termo* also, the most abundant bacterium-eating protozoan, gave us an average of 210 to the cubic centimeter above the dam at Marseilles, but fell to an average of 54 to the centimeter at Starved Rock. The Lake Michigan diatoms, on the other hand, continued in nearly constant numbers, as did also the clean-water unicellular algæ and green *Protozoa*.

In the Starved Rock-Chillicothe section of the river the outstanding feature of the plankton was the marked increase in diatoms and other chlorophyll-bearing unicellular organisms, plant and animal, which became sufficiently abundant by the time Hennepin was reached to give the water a characteristic greenish tinge. This was largely due, however, to the picking up numbers of a single species of diatom, *Melosira granulata* var. *spinosa*, a form common in the Illinois River and especially in its backwaters. This "greening up" of the water below La Salle was noticed, in fact, on a down-stream trip in June, 1910, and was conspicuous to the naked eye in both 1911 and 1912, most noticeably so at the lowest water-levels. Rise of water and an increased turbidity due to flooding rains in early August, 1911, obscured it for a time. It will presently be seen that these indications of a radical change about Hennepin in the biological contents of the water, are supported by the products of longshore collections, for it is here that the foul-water blue-green algæ began distinctly to diminish, that the Cladophoras and *Stigeoclonium lubricum* began to take the place of *Stigeoclonium tenue* as the most abundant green algæ,

and that the amphipod crustacean, *Hyalella knickerbockeri,* put in its first appearance below Dresden Heights.

The Sanitary Canal at Lockport

Our data for the sanitary canal were obtained at Lockport, three and a half miles above the lower locks through which the canal empties into the Des Plaines. They were derived from biological collections made at this point September 25, 26, and 27 and November 1, 1911, and August 9 and October 7, 1912; and from chemical determinations made November 1, 1911, and February 7, March 18, November 1, and November 13, 1912. The biological data thus represent the conditions of late summer and autumn, and the chemical data, those of autumn and winter, but neither apply directly to those of spring or midsummer.

General and Chemical Conditions.—At the time of the first visit, September 25, 1911, the water of the canal at Lockport was clear, like that of Lake Michigan, with much less silt and other suspended matter than the Des Plaines at the same point. It had a slight sewage odor, not particularly offensive; and there was no emission of bubbles of gas to indicate rapid fermentation or putrefaction of its contents. Miscellaneous offal and other refuse was floating or stranded along the edge of the canal, much of it but little decayed. In it were recognized grains of corn and wheat, melon seeds, tallow, pieces of entrails, bits of human excrement, pieces of old newspaper and toilet paper, fragments of finely chopped straw, and street sweepings. The grayish sludge at the bottom of the canal had a foul privy odor combined with a tarry smell like that of the sludge from the bottom of the Illinois River at Morris on the same date.

Under the colder weather conditions of November 1, 1911, with a surface temperature of the water at 50° F., the odor and general appearance were practically the same as in September. There was perhaps even less appearance of decay in the floating debris. Chicken entrails floating in the water of the canal looked, in some cases, almost fresh.

August 9 of the following year the color, odor, and general condition of the canal water were practically like that of September, 1911. The water temperature was 64 to 65 degrees F.; and the depth of the water in the canal was three to four feet above that of the fall of the preceding year.

The dissolving oxygen of the water, as shown by chemical tests, ranged from .4 of one part per million November 1, 1912, to 9.3

parts per million, February 17 of the same year. At the temperatures of the time, the first of these ratios was equivalent to 3.5 per cent. of oxygen saturation, and the last to 64.9 per cent. The average of the six observations made, was 4 parts of oxygen per million, or 31.9 per cent. of saturation. The general conditions were thus those of lake water rather heavily loaded with organic debris which had not yet undergone any great degree of putrefaction.

Plants and Animals.—Consistently with this statement, in September, 1911, a few small shiners (*Notropis atherinoides*) one to two inches long, were alive in the water, although in a dying state; but all the larger minnows of this species, together with many spottailed minnows (*N. hudsonius*), silvery minnows (*Hybognathus nuchalis*), and lake perch, were stranded, dead, along the shores. In the cooler weather of November, 1911, a larger proportion of the shiners were alive, and a single large fish, possibly a carp, was indistinctly seen moving away from the riprap at the north shore. All the fishes found, were common Lake Michigan species. A single frog was the only other vertebrate taken.

A cursory examination of the bottom sludge November 1, 1911, showed no signs of animal life; and the only insects seen in or on the water were a back-swimmer (*Notonecta*) and several waterboatmen (*Corixa*), both of which, as they breathe air, can afford to be indifferent to a deficiency of dissolved oxygen. No snails or crustaceans were found in the water at this place in either year. Along the riprap at the edge of the canal in 1912 was a mixture of normal and septic species of algæ, with others representing medium stages of contamination. The most abundant clean-water species were *Ulothrix zonata* and *Schizomeris leibleinii*, barely submerged on the riprap, where they were mixed with *Oscillatoria limosa*, to be classed as a contaminate species. There were occasional slight traces of *Sphærotilus natans* and *Beggiatoa alba*, both highly distinctive of septic or polluted waters, together with considerable growths of *Stigeoclonium tenue* (a contaminate form) and *Chlorella vulgaris*, the latter encrusting stones. Among the meshes of the marginal algæ were many septic *Protozoa* and rotifers (*Bodo saltans, Vorticella microstoma*, and *Rotifer actinurus*), together with others common in polluted waters (*Oikomonas termo, Monas vivipara*, and *Anthophysa vegetans*).

Des Plaines River, Lockport

September, 1911.—In late September of 1911 the Des Plaines at Lockport was much more offensive than the sanitary canal, its

organic contents being evidently in a far more advanced stage of decomposition. The stream was very low, flowing, at a depth of six inches to a foot, over stones and pebbles which were completely covered with a septic growth of *Sphærotilus* and algæ, mainly blue-green species. The water had a grayish look, and a filthy smell, which may perhaps be best described as a mixture of fishy and privy odors. The current was too swift to permit the deposit of much sediment; and it was frequently dislodging and carrying away fragments of the incrusting growth from the bottom. A comparison of the contents of the stream with those of the sanitary canal beside it pointed to the conclusion that the septic organisms of the upper Illinois were at this time being derived mainly from the Des Plaines and not from the canal, although the putrescible matter carried by the latter furnished an abundant nourishment for their growth and multiplication far down the course of the main river. The Des Plaines was a seed-bed, in short, and the canal water the soil, for the culture of sewage organisms in the Illinois.

Our collections from the river at Lockport were made opposite the Ninth Street Bridge, three miles and a half above the lower gates of the canal. *Sphærotilus natans* and *Anthophysa vegetans* were very abundant, with *Carchesium lachmanni, Epistylis plicatilis, Vorticella microstoma,* and *Paramecium caudatum* intermixed. Less distinctly septic forms were *Oscillatoria limosa* and *Stigeoclonium tenue*, with some *Ulothrix zonata.* Among tangles of dirty *Sphærotilus* were found large numbers of *Chironomus* larvæ, together with oligochæte and nematode worms. No fish were seen here in September, the water being evidently much too foul for even the most indifferent species.

November, 1911.—November 1, 1911, the stream was six to eight inches deeper, and the water temperature was 57° F., but conditions generally were not unlike those of September, except that the odor was less offensive. No snails or higher crustaceans could be found, although there were now great numbers of mosquito larvæ in the water. There were also many shiners (*Notropis atherinoides*), nearly all alive but mostly in a dying state, as if they had been carried down by the current from above, and overpowered by the toxic contents of the stream.

The content of dissolved oxygen was higher in the Des Plaines than in the sanitary canal—22 per cent. of saturation in the canal and 44 per cent. in the Des Plaines; and virtually the same relations were found again in November, 1912. February 2, 1912, on the other hand, the oxygen was nearly the same in both waters—9.3

parts per million in the canal, and 8.8 parts in the Des Plaines. The same was true March 18, when 6.3 parts of dissolved oxygen were found in the canal and 6.5 in the Des Plaines.

August and September, 1912.—Additional biological collections were made August 9 and September 30, 1912, with water temperatures at 67° F. on the first date and 64° on the second. The stream was rather low, with much vegetation, including water milfoil (*Myriophyllum*), *Elodea,* pondweed (*Potamogeton*), etc., the first two mainly on the west side. There was, in fact, a marked contrast at this time between the two sides of the river, due to the fact that the water of the east side was badly contaminated by a waste ditch flow from the sanitary canal, and contained there the sewage organisms noticed the preceding year. In the *Cladophora* of the west side were many live minnows, sunfish, etc., with *Spirogyra, Vaucheria,* duckweed, and epiphytic green algæ. Here also among the *Cladophora,* on the west shore, were numerous crustaceans—*Cyclops, Simocephalus,* and *Ostracoda,* together with *Hyalella dentata* and a single specimen of *Asellus.* On the east side there was an abundance of *Carchesium* on the stones, together with oligochæte worms (*Tubifex*) under mats of *Oscillatoria. Eristalis* and *Odontomyia* larvæ were taken in the contaminated water; and *Corixa* and *Zaitha* and larvæ of *Simulium* and caddis-flies among *Cladophora* on the west shore. The mollusks obtained were *Lymnæa humilis, Physa gryina,* and *Planorbis parvus* and *trivolvis;* the first on the east side and the others common on the opposite shore.

Des Plaines River at Dresden Heights

The midsummer condition of the mingled waters of the sanitary canal and of the Des Plaines at the mouth of the latter was shown by observations made at Dresden Heights, in July and August, 1911, where typical septic organisms predominated. From July 26 to August 1 this water had a grayish, sloppy appearance, with a mingled fish and privy odor. Sticks and stones were everywhere hung with tufts of two of the most abundant septic organisms, *Sphærotilus natans* and *Carchesium lachmanni.* These were being continually torn loose from their attachments and carried down stream, where they appeared abundantly in the plankton; and silt and other sedimentary matter was kept churned up in the current so that there was scarcely any accumulated sludge on the broken stones and boulders of the bottom and dam. The temperature of the surface layer of the water July 28 was 68° F. No fish could be found here

at this time, either dead or alive. It was here also that the largest number of septic organisms per cubic centimeter of water was obtained July 28 to August 3, by our modification of the Kolkwitz method,—186 per centimeter, as compared with 116 at Morris and 15 at Marseilles. Of the pollutional species, on the other hand, there were 55 per cubic centimeter at Dresden Heights as compared with 169 at Morris and 35 at Marseilles, while of the contaminate forms, there were 90 at Dresden Heights, 76 at Morris, and 28 at Marseilles. The mixed origin of the waters at this point was especially illustrated by the further fact that clean-water species averaged 209 per centimeter at Dresden Heights, 287 at Morris, and 270 at Marseilles. At Dresden Heights, however, these were almost wholly diatoms characteristic of Lake Michigan water, which had evidently been brought down by the sanitary canal. The most significant of these were two species of *Tabellaria—T. fenestrata* and *T. flocculosa* —together with *Fragilaria virescens* and *Cyclotella kützingiana*. The Tabellarias were never taken in our Illinois River plankton previous to the opening of the sanitary canal, and their maximum number in the Illinois in these 1911 collections came from above Marseilles. The other two species formerly occurred in both the river and lake, but they were rare below Morris in July and August of 1911—a strong indication of the Lake Michigan origin of those taken at Dresden Heights.

The water here July 27, at a temperature of 68° F., gave us an average of 13.1 per cent. of oxygen saturation as the mean of determinations made at 10 a. m. and 1:30 p. m., the Kankakee River giving us, on the other hand, just above the mouth, an average of 126.8 per cent. at 2 p. m., at a temperature of 71.6° F. In other words, the Kankakee, supersaturated with oxygen, contained nearly ten times as much as did the Des Plaines just above the junction point of these two rivers. The former held in solution, on the other hand, only one sixth as much carbon dioxide—2.1 parts per million to 12.8 parts in the Des Plaines. The oxygen content of the latter was practically the same September 26, 1912, as in the midsummer period of the preceding year, but increased greatly in fall, reaching 40.3 per cent. of saturation November 14 as compared with 11.2 per cent. September 26.

Biological conditions were but little changed in 1912, as shown by visits made in August and September of that year. As before, no fishes were found, and no other vertebrates except a single frog. Many dead shells of gastropod mollusks were seen, including *Planorbis trivolvis, Physa gyrina,* and *Lymnæa palustris*, and a single speci-

men of the last species was found alive among algæ in the drift. Numerous *Chironomus* eggs were in the same situation; and air-breathing beetles—*Dineutes* and *Gyrinus*—were also common, but there were no water-breathing larvæ except *Chironomus*. Slime worms (*Tubificidæ*) were rare in the soft black sludge at the bottom and the edge of the stream—a great contrast with conditions at Morris to be reported later. *Sphærotilus* was again very abundant on weeds and sticks, and on old stems of *Carchesium lachmanni*. Blue-green algæ, chiefly *Oscillatoria limosa* and *Phormidium uncinatum*, were fairly frequent. The green filamentous algæ, *Stigeoclonium tenue*, and *Spirogyra*, chiefly *S. vernata*, were common in both August and September, and *Ulothrix zonata* in the latter month; and some *Lemna* and *Wolffia* were caught in the drift along the bank. *Protozoa* were represented mainly by fixed forms, especially by *Carchesium*, attached to sticks or floating in the water. There were no sponges, hydroids, leeches, planarians, or crustaceans.

The general impression to be gained from these midsummer and autumn data is that of a heavily polluted stream with less oxygen and more carbon dioxide than was consistent with the life of fishes, mollusks, insect larvæ, or crustaceans, and with the natural fauna of the stream represented by saprobic organisms, except at its edges, where oxygen enough was absorbed from the air to serve the needs of a few green algæ and an insignificant group of associated animals. Decomposition of its sewage materials had not yet reached its climax, which came at Morris and Marseilles at low water in the hottest weather, and at various distances farther down when the water was higher or the weather cooler,—farthest, of course, when these conditions were coincident.

The Kankakee River at Dresden Heights

Conditions in the Kankakee at its mouth are particularly interesting and important since they give us a close approximation to those of the natural water of the Illinois River, derived, as they are, from a territory similar in character to the valley of the Illinois below, and contaminated but slightly, if at all at this place, by way of contributions from comparatively small towns at some distance above. Collections were made from the Kankakee at a point near the east bank and two hundred yards above the mouth of the stream. The samples were taken in two or three feet of water by wading out or by working from an improvised trestle forty feet in length. The river at this point is broad and shallow, with a moderately swift current, probably two to three and a half miles per hour, becoming

much quicker, however, as it approaches the rapids at the junction with the Des Plaines. The water was more or less yellow with clay silt. The color, odor, and the organisms obtained, were those of a clean and practically uncontaminated stream. The water temperatures at the surface were 69.7° F. July 24, 72.4° July 26, 82.5° August 9, and 73° August 21.

Nine determinations of oxygen were made on different dates,—July 24 and 26, August 10 (forenoon and afternoon), and August 21 (forenoon and afternoon), 1911; and February 19, September 26, and November 14, 1912. Four tests for carbon dioxide were also made—July 26, August 10, and August 21 (forenoon and afternoon), 1911. Six of the nine oxygen determinations showed that the water was supersaturated, percentages ranging from 104.6, September 26, to 133.1 on the afternoon of August 10. The lowest result was 62.2 per cent. of saturation on February 19. The general average of the nine determinations is 103.8. Forenoon and afternoon tests for the same day were made August 10 (10:30 a. m. and 2:30 p. m.) and August 21 (10:30 a. m. and 2 p. m.). Those for the forenoon averaged 101.7 per cent., and those for the afternoon 121.2 per cent. The afternoon increase was doubtless due to the liberation of oxygen by submerged plants under the influence of sunlight. The carbon dioxide found July 26 was 2.1 parts per million; August 10, .7 parts; and August 21, none.

The biological conditions were those of a clean stream, there being no plants or animals obtained here in either year commonly classed as saprobic—no blue-green algæ, no *Carchesium* or other fixed forms of *Protozoa,* no oligochæte worms, and no *Sphærotilus* or *Beggiatoa.* Green filamentous algæ—mostly *Cladophora glomerata,* with some *Microthamnion* and *Vaucheria*—many river mussels—the greater part of which were, however, for some unknown reason dead—and several water snails (*Goniobasis*), were among the commoner clean-water forms.

Illinois River at Morris

The water here was grayish, sloppy, and everywhere clouded with tufts of *Sphærotilus* and *Carchesium.* The odor was continuously foul, with a distinct privy smell in the hottest weather. Bubbles of gas were continually breaking at the surface from a soft bar of sludge formed along the north bank between Kindlespire's landing and the Mazon bridge. On the warmest days putrescent masses of soft, grayish black, mucky matter, from the diameter of a walnut to that of a milkpan, were floating on the surface. These masses,

held together by threads of algæ and fungi and growths of branching colonial bell-animalcules, rose from the bottom buoyed up by the gases developed within them, but settled quickly when they were broken apart by a light touch. Noticeably cleaner water, with a less offensive smell, carrying also much less *Sphærotilus* and *Carchesium,* was found along the south shore, where the Kankakee contribution still had a discernible influence. The water temperatures of the surface layer were 69.1° F. July 28, 73° August 11, and 73° August 23.

October 11, when the water was three feet higher than in August, conditions were greatly improved, the water being much less offensive in odor, with no bubbling of gases and no floating masses of detached sludge. The feathery tufts of *Sphærotilus* and *Carchesium* were also much less abundant. Virtually the same statement may be made for November 3, when the river level was about two feet above that of the midsummer season, and for November 13, when it was two or three feet higher still.

Imperfect Mixture of Waters.—A study of conditions at Morris was made difficult by the fact that the waters of various origin flowing past that point were not yet thoroughly mingled, those of the Kankakee predominating along the south bank and those of the Des Plaines River and the sanitary canal along the north bank, while the midstream current was made up of a variable mixture of the two. This was most plainly shown by a comparison of the chemical reports of the oxygen content of the water, on the same days but on opposite sides of the stream. Determinations of oxygen, available for this comparison, are as follows, stated in percentages of saturation.

Date	*North side*	*South Side*
September 13, 1911	9.70	21.40
September 27, 1912	17.90	37.40
November 2, 1912	41.40	56.00
November 14, 1912	54.60	73.10
February 17, 1912	45.80	52.85
March 19, 1912	65.40	73.80

The differences between the two sides of the stream varied with the weather and with the stage of water, being greater in hot weather than in cold, and greater also in high water than in low. In the former case the more rapid decomposition of the organic matter appropriated the oxygen more completely by the time the water of the northern side of the river had reached Morris. The degrees of

saturation with oxygen for the southern, or Kankakee, side were 113 per cent. larger in September, 1911, than those of the northern, or Des Plaines, side; 34.5 per cent. larger in November; and 13.9 per cent. larger in February and March, 1912. Flooding rains, on the other hand, tend to increase the difference and to carry it further down the stream. The clean Kankakee being a much larger river than the polluted Des Plaines, the effect of a strong rise in these streams is to increase the ratio of south-side unpolluted water to north-side polluted water, and to carry a larger volume of the former down to Morris and even to Marseilles, with less admixture than at low-water stages. This condition was illustrated by observations made November 3, 1911, when recent heavy rains had brought the river up about three feet. Midstream ratios, samples for which were taken from what was obviously Des Plaines River water, averaged 4.6 parts per million of oxygen, while south-shore samples (Kankakee water) contained 10.8 parts per million. The water temperature at this time was 41° F.

All our midstream samples were taken for analysis as near the center of the river as practicable, and usually from a depth of eighteen inches or two feet below the surface. Midstream ratios averaged 7.3 per cent. of saturation in July, 1911, 16.37 per cent. in August, 28.5 per cent. in November, and 48.76 per cent. in February, 1912. In September, 1912, they stood at 17.9 per cent., and November 14 at 57.2. This is the highest of our midstream readings; but a still higher one might have been obtained March 19, 1912, when even the north-shore ratio was 65.4 per cent., or 9.2 parts per million, with a temperature of 34.7° F.

Oxygen determinations were made on the same date from both sides and from the center of the river on only three days—February 16, September 27, and November 14, 1912. On these days the midstream percentages were much nearer to those of the northern or heavily polluted side than to those of the southern or lightly contaminated side, the mean difference being 3.7 per cent. in the first case and 48.4 per cent. in the second. In this we may probably see the effect of the wing-dam at the mouth of the Des Plaines in forcing the water of that stream well across the Illinois, leaving a comparatively narrow strip of imperfectly mixed Kankakee water along the south bank.

Extreme Midsummer Conditions.—The lowest ratios of oxygen at Morris were those of July 22, 1911, when samples were collected from the middle of the stream and from the south bank only, the former at a depth of five feet, and the latter at three feet below the

surface and forty feet from the bank. The south-shore samples averaged .21 parts per million, which, at the temperatures of the time, was equivalent to 2.65 per cent. of saturation, the corresponding figures for the midstream samples being .267 parts per million, or 3.1 per cent. of saturation. The water temperatures on this date ranged from 66.7° F. at 10 a. m. to 77° at 1:30 p. m.

Midstream samples showed no increase of oxygen in the afternoon, the parts per million, July 22, being .30 at 10 a. m., .26 at 1:30 p. m., and .24 at 4 p. m.; but those taken forty feet from the south bank were .04, .28, and .31 for the same hours, respectively.

The effects of sewage contamination are clearly shown by a comparison of these data with the Kankakee determinations of July 24 and 26, both made at 2 p. m., which stand at 9.91 parts per million for the first date, and 11.21 parts for the second—equivalent to 107.9 and 126.8 saturation percentages, respectively. The means of the Morris determinations for afternoon hours were thus but 2.3 per cent. of those for the Kankakee; in other words, over 97 per cent. of the oxygen normal to these waters had been removed from them at this time by decomposition processes due to the amount of their organic contents.

The Bottom Sludges.—The silt and other deposits accumulating on the bottom of a stream are in some respects more significant of its average condition than are the waters of its current, especially so as many of our fishes obtain the greater part of their food from the bottom, upon which most of the plants and animals necessary to their support live continuously. The current opposite Morris is so rapid that the bottom is practically clean of sludge except where eddies and slack-water places are especially favorable to sedimentation. An extensive bar of sludge from three to eight feet deep has been formed in such a place between the wagon bridge and Kindlespire's landing, along the north shore of the Illinois. The upper two or three feet of this deposit, except for a thin upper stratum of grayish color, is a soft black ooze of homogeneous composition and a strong offensive odor. It contained, from September on, immense numbers of tubificid worms, in which respect it differed from the canal deposits at Lockport, which reached at the controlling works a depth, in places, of three or four feet. Plates of this sanitary-canal sludge spread out in thin layers and kept for thirty-six hours showed to the naked eye no signs of life.

An extensive deposit of sludge, five or six feet deep in places, has formed at the lower end of a large island half a mile above the Marseilles dam, and sediments a foot or more in depth have accumulated also in the chutes on each side of this island. In the north

chute, the main channel of the stream, the sediment was fine, heavy, black, and but little offensive, and contained few tubificid worms, the lighter organic matter evidently being carried down by the current; but in the more sluggish water of the south chute it was light, soft, and grayish, and full of *Tubificidæ*. For the first half mile above the dam the river bottom is mostly rock, covered by a thin layer of very soft ooze; but below the dam the swift flow of the stream keeps the bottom bare.

The chemical condition of the bottom deposits at this time is shown by the following table of the results of analyses of gases collected from the bottom sediments of the Illinois, at Morris, in August, 1911.

	Carbon dioxide	Oxygen	Carbon monoxide	Methane	Nitrogen
1	19.45	0.0	0.69	79.30	0.56
2	19.31	0.0	0.32	79.51	0.86
3	18.12	0.09	0.68	78.97	2.14
Means	18.96	.03	.56	79.26	1.19

This table is made more significant if it is brought into comparison with the following data of analyses obtained from the gases of the septic tanks of two sewer systems of Illinois towns.

	Carbon dioxide	Oxygen	Carbon monoxide	Methane	Nitrogen
Collinsville	17.98	0.23	0.34	81.26	0 0
Naperville	19.06	0.0	0.10	74.50	6.34
Means	18.53	0.11	.22	77.88	3.17

It will be seen that all of these samples are alike characterized by the virtual absence of oxygen, by the large percentages of carbon dioxide, and by the predominance of marsh gas or methane (CH_4), and that the Illinois River gases are indistinguishable from those of the tank sludges of the town sewers. The abundance of carbon dioxide and the absence of oxygen are, of course, to be understood as due to organic decomposition in the presence of oxygen; and the methane is evidence of the continuance of decomposition after the available oxygen was exhausted.

Collections of the bottom gases were made again at Morris September 5; and with a view to learning how far down the stream the bottom conditions found at this point were continued, like collections were made at Henry September 6, and above the dams at Marseilles. The chemical results are as follows.

	Carbon dioxide	Oxygen	Carbon monoxide	Methane	Nitrogen]
Morris	22.67	0.0	0.25	74 48	0.0
Marseilles	17.79	0.02	0.27	81.91	0.0
Henry	14.87	0.22	0.47	71.37	13.06

Sludge Worms.—It is clear that neither plants nor animals requiring oxygen could live in these sediments at the bottom of the stream. The abundance of *Tubificidæ* (*Limnodrilus* and *Tubifex*) imbedded in this sludge is explained by the extraordinary respiratory capacity of these worms, and by the fact that their respiratory structures are situated at the anal end of the body, which projects above the bottom and is kept continually waving back and forth. Their circulatory system likewise specially adapts them to life in water with a minimum amount of oxygen, the blood containing sufficient hemoglobin in solution to give it a red color, and being kept in active circulation through a closed system of blood-vessels.

Composition of the Sludges.—The following is a table showing the general composition of the sludges themselves according to analyses kindly obtained for us by the division engineer of the Sanitary District of Chicago, Mr. Langdon Pearse, the samples for which were furnished by ourselves at his request.

1911	Source	Specific gravity	Per cent. moisture	Per cent. in terms of dry matter			
				Nitrogen	Volatile matter	Fixed matter	Ether soluble
Sept. 5	Morris	1.21	69.2	0.64	14.8	85.2	1.18
Sept. 6	Marseilles	1.16	73.7	0.72	16.8	83.2	1.38
Sept. 6	Henry (above dam)	1.27	61.5	0.48	10.1	89.9	0.40

The greater specific gravity, the diminished moisture, and the smaller percentages of nitrogen and of fats in the sediments above the Henry dam, all indicate less organic matter in proportion to the

inorganic materials of the silt. As there is no reason to suppose that the river was carrying a larger load of mineral substances at Henry than at Marseilles, the differences of the table are probably due in part to a settling out, and in part to a decomposition of organic contaminations before the river water reached the Henry dam.*

Marginal Conditions, July, 1911.—The septic conditions above described were general at Morris for the stream as a whole, but were considerably modified along the margin in very shallow water, especially in pockets protected against the current. Water an inch deep near the north bank contained 3.5 parts per million of oxygen in the forenoon of August 31 and 6.1 parts in the afternoon, (38.9 per cent. and 69 per cent. of saturation,) while midstream samples gave 1.05 and 1.18 parts per million at the same hours (11.4 per cent. and 13.3 per cent. of saturation). The green-thread alga, *Stigeoclonium tenue,* formed many patches on the bottom even in July, in water four to six inches deep; and the oxygenation of the marginal water was largely the work of these plants. Here also were very many tubificid and naiid worms (*Tubifex* and *Dero furcata*), together with aquatic insects (*Notonecta, Nepa,* and *Gyrinidæ,* and a few *Chironomus* larvæ); but there were no clams (*Unionidæ*) or snails or crawfishes or larvæ of May-flies or of dragon-flies.

Plants and Animals of the Stream in general, July, 1911.—Generally speaking, the plants and animals of this part of the river in July, 1911, were either conspicuous by their absence, if clean-water forms, or by their excessive abundance, if pollutional or contaminate species. *Sphærotilus natans,* for example, was hanging to every stick or grass-blade along the edge, and to every suspended particle, small or large, and was attached everywhere to the stems of branching *Vorticellidæ*, especially to *Carchesium lachmanni.* Specks or larger collections of these two latter most abundant foul-water forms were so numerous, indeed, as to give the water a grayish look. There was every indication that these characteristic sewage organisms were coming at this time mainly from the Des Plaines above the mouth of the canal, and not directly from the sanitary canal itself, in which, in fact, they were not then abundant. The microscopic population of the large, soft masses floating down stream at Morris in July was mainly made up of a great variety of fungi, algæ, *Protozoa,* and rotifers, of which the most abundant were *Sphærotilus natans, Oscillatoria limosa, Colpidium colpoda, Carchesium lachmanni,* and *Rotifer actinurus.*

No fishes were seen or heard of here in the Illinois during this

*For additional data concerning the sludges in the winter time, and for all sections of the river, see p. 552.

month, although they were abundant in Mazon Creek, and in the slough at its mouth, which opens into the Illinois at Morris. Carp were noticeably numerous in this slough, and could be seen any sunny morning lined up along the edge of the river current, occasionally venturing into it a short distance, but quickly returning. After August 10, when rains brought the river up about six inches, the carp began to come out of the slough into the river along the south bank.

Late Summer and Autumn Conditions, 1911.—Towards the end of July, cooler weather and higher water produced changes which presently had their effect on the life of the river. The midstream temperature was 6.7° F. cooler on the 28th of July than it had been on the 22d, and a heavy rain August 10—the first excepting one light shower since our operations began, July 15—brought the river up about six inches. The fall rains began about the middle of September, and the river rose until, by October 5, it was four to five feet above the mid-July level. It then fell slowly about three feet in October, was brought up again a foot by November 11, and by the end of that month had declined to two and a half feet above the July stage. Water temperatures in the midstream ranged from 63° to 72° F. in August and September, and by November 3 (at 9 a. m.) were down to 41°. The midstream oxygen ratios of this late summer and autumn season averaged 1.44 parts per million in August, and stood November 3 at 4.55, or 16.5 per cent. of saturation for August and 41.3 per cent. at the beginning of November.

Reappearance of Fishes and other Animals.—By October, fishes had begun to appear to some extent in the river, even along the northern or contaminate side, where a few young perch, shiners (*Notropis atherinoides*), straw-colored minnows (*N. blennius*), and a single top-minnow (*Fundulus notatus*), were taken in places protected from the strong current. Shiners and straw-colored minnows were seen again in the same situations November 3, and carp were occasionally noticed on the south side of the river during the latter part of October. December 2, the first systematic attempt to take fishes at Morris was made, by hauling repeatedly a hundred-and-twenty-foot minnow seine in slack water along the north bank. Although weeds and sticks were slimy with *Sphærotilus natans* and *Carchesium lachmanni,* which were also floating in the shallows, numbers of young perch three to six inches long were captured here, together with many shiners—two to four inches—and a single black bullhead (*Ameiurus melas*), three inches long. An examination of the stomachs of these specimens showed that none of them had

recently taken food; but no other evidence of any abnormal condition was found.

Other and smaller animals, not detected in July, also made their appearance here as the season advanced. Water snails (*Planorbis* and *Lymnæa*) were seen on the south side of the river in August, and specimens were repeatedly taken on the north side from the first of September on. October 28 a large crawfish was noticed, apparently distressed however, and trying to leave the water. Large numbers of *Entomostraca* (*Cyclops prasinus*) were taken in the stream October 13, although only a few dead nauplii had been collected previous to that time. Female *Cyclops* bearing eggs were noticed in shallow water in protected pockets along the north shore after the September rise had scoured the river out. From November 1 to 8, healthy *Entomostraca,* largely a species of *Diaptomus,* were taken in considerable numbers both here and in the sanitary canal at Lockport, and free living nauplii were common in the collections from the sanitary canal.

Winter Conditions, 1912.—Winter conditions in February and March of 1912, when the river at Morris was partly frozen, were naturally in notable contrast to those of the midsummer season. The river level was unusually low for the winter, ranging from six inches to a foot above that of the preceding August. The water temperatures were, of course, near freezing. The mean of nine observations made February 16 was 33.8° F., and that of two observations made March 19 was 34.7°. There was doubtless no less organic matter in the water than before, and the sludge from the bar on the north side had now a strong privy odor, as of undecayed human feces, in place of the merely rank smell of the warmer weather. The water itself had a sloppy odor, and was apparently carrying more *Carchesium lachmanni* than in midsummer. Decomposition being, however, much slower at the winter temperatures, the oxygen content of the water was relatively high, ranging, February 16, from 6.3 to 7.2 parts per million, equivalent to an average saturation percentage of 48.76 for midstream samples.

The Winter Search for Fishes.—Persistent efforts were made at this time, under unusual difficulties, to learn whether fishes were to be found at Morris under these winter conditions. The use of minnow-seines, river-seines, and fyke-nets, was supplemented by repeated explosions of half-pound sticks of dynamite in different parts of the river. To haul the seines it was necessary to cut out the shore ice to a depth of one or two feet in order that the nets might be landed. In this way a dozen hauls were made with a 150-foot

seine of one-inch mesh. The nets fished well, as a rule, as far as seventy-five feet from shore, in the full current with water four to nine feet deep, but no living fish were taken by any of these hauls. Two dead shiners were in the net February 18, and a small specimen of the same species, in a dying condition, was picked up by hand near the shore February 24. It had perhaps been washed in from Au Sable Creek. A hoop-net, with a 6-foot opening, and two smaller fykes with 2-foot and 3-foot openings were kept continuously fishing from February 20 to March 2, alternating between the north and the south shores, but not a fish was taken by them at any time. Twenty-four sticks of dynamite were exploded on both sides of the river and in the midstream, but the only fish to appear was a single shiner, near the south shore, a hundred yards above the mouth of Mazon slough. February 28, a neighboring farmer found a 15-pound carp on the ice near the north shore below Au Sable Creek. The fish was probably sick or suffocated, and trying to get air. On the 2d of March, several perch and shiners, and a single carp eight or ten inches long, were taken in cleaning out the pump-house tank of the Rock Island Railroad, the intake of which is seventy-five feet from the north shore of the stream. As the tank had last been cleaned February 1, these fish must have been pumped in since that date. The stomachs and intestines of all the specimens taken at Morris between February 16 and March 2 were quite empty.

Summer and Fall of 1912.—In August and September, 1912, Morris was twice visited for systematic collections of fish and of the shore and bottom forms of animals and plants—the first time August 1 to 10, and the second, September 23 to October 1. The river level stood, in the beginning, at twenty inches above the July stage of 1911, fell slowly to eight inches above by September 22, and then rose to eleven inches by the end of the month. Specks of suspended matter, largely *Sphærotilus* and *Carchesium*, gave the water a grayish hue, and its smell was the same as in the summer of 1911, but less offensive. There was also less bubbling of gases from the bottom, but the odor of the sludge was not noticeably different.

Chemical determinations were made during this period only on the 27th of September, at which time, with a water temperature of 62.7° F., the oxygen reading for both the north shore and the main stream was 17.9 per cent. of saturation (1.8 parts per million), and that for the south side was 37.4 per cent. (3.7 parts per million).

Persistent fishing was done with dip-nets, seines of various sizes, set-nets, trammel-net, dynamite, dredges, and the mussel-bar,—the last for Unios. Seven fishes were taken at this point in all—five of

them black bullheads (*Ameiurus melas*), one a rock bass (*Ambloplites rupestris*), and one a blue-gill sunfish (*Lepomis pallidus*). These were all taken in set-nets in the less polluted water of the southern or Kankakee side of the river—the bullheads near the outlet of Mazon slough, and the rock bass and sunfish about seventy-five yards above. They were the entire product of a haul of the 200-yard seine, made on the north shore August 2; five settings of the trammel-net on the south side of the river; continuous fishing with three and four set-nets August 2 to 9; fifteen hauls with small seines made on both shores, September 25; and the explosion of twenty half-pound sticks of dynamite, August 2 to 9, near both shores and in the middle of the stream. The river here was, in fact, practically destitute of fishes, and the few taken were in close proximity to the Mazon slough. Moreover, some of the bullheads were "fungused" or in otherwise unwholesome condition.

The only other vertebrates taken here were a single frog, two snapping turtles, and a soft-shelled turtle. The search for mollusks yielded seven species of mussels, all the specimens dead, however, except for one collection made in Mazon slough. Snails were obtained several times—*Campeloma, Goniobasis,* and *Pleurocera* all dead, but *Planorbis, Physa,* and *Lymnæa* alive in part, six collections containing living specimens of these genera and nine collections containing dead. No *Sphærium* or *Pisidium* were taken here, nor any *Bryozoa,* sponges, or hydroids.

Numerous samples of sludge from the bottom were spread in thin layers on plates, and left for the animals to emerge, with the result that tubificid worms appeared in numbers varying from 12 to 200 per plate. These were most abundant in samples taken nearest the shores. There were no leeches or planarians in our collections, but four of them contained naiid worms (*Dero furcata*). A single crawfish was taken in Mazon slough, and bleached, unwholesome-looking specimens of an amphipod crustacean (*Hyalella knickerbockeri*) were present in the duckweed along the south bank. Several species of water-beetles and water-bugs were found along both shores, but, with the exception of larvæ and pupæ of *Chironomus*, these were all adults which take their oxygen from the air and not from the water. There was some pondweed (*Pontederia*) and duckweed (*Lemna* and *Wolffia*) along the banks.

No later collections were made at Morris in 1912, but we have additional oxygen determinations for November 2 and November 14. The following table gives these data for the midstream and the two shores on these two dates.

	Date	Temperature F.	Oxygen	
			Parts per million	Per cent. saturation
North shore	Nov. 2	48.2	4.8	41.4
North shore	Nov. 14	46.4	6.5	54.6
Midstream	Nov. 14	46.4	6.8	57.2
South shore	Nov. 14	46.8	8.7	73.1
South shore	Nov. 2	48.2	6.5	56.

Illinois River at the Marseilles Dam

Above the Dam.—In midsummer, 1911, the water at the Marseilles dam had a grayish look and a disagreeable odor, but with perceptibly less material in suspension than at Morris. There was no bubbling of gases from a bar of sludge at the point of the island half a mile above the dam, but chunks of sludge were floating to the surface on the warmest days. The odor of this bottom sediment was the same as at Morris and from the sanitary canal at Lockport. The surface temperature was 71° F. July 30, 72° August 11, and 71.9° August 24.

The situation a quarter of a mile above the dam may best be described by a comparison with that at Morris, these points being but seventeen miles apart, with no important tributary of the river or other modifying factor coming in to interfere with the spontaneous development of conditions within the stream itself. Another important and interesting comparison is that of chemical and biological data from above and from below this dam, since this comparison will show us what and how great are the effects of the fall upon a polluted water.

We may notice first that the mixture of Kankakee and Des Plaines water was evidently complete above the dam at ordinary stages, the two shores and the middle of the stream differing but little in respect to their ratios of oxygen and carbon dioxide, and not always in the same direction as at Morris. The north, or Des Plaines, shore water at Marseilles was, indeed, somewhat more oxygenated than that of the south, or Kankakee, shore water, both in February and in August, 1912—the only months when tests available for this comparison were made. More precisely, the north side oxygen ratios were 3 per cent. higher than those on the south side February 20 to 22, and 11 per cent. higher August 21; while the midstream percentages were a little lower than those of either shore in February, and a little higher than either in August. Such differences may be regarded as either

negligible in amount or due to local conditions. In November, 1911, however, after a flooding rain which brought the river up some three feet, midstream water above the dam contained thirty per cent. more oxygen than north-shore water below the dam—a relation the reverse of that found at this point at any other time. This can only be understood as due to the fact, already commented upon under Morris, that, at this stage of the river, Des Plaines and Kankakee waters were still imperfectly mixed even at Marseilles. The midstream samples, taken nearer the south shore than the north, were evidently Kankakee water, and the north-shore water, on the other hand, was still essentially that of the Des Plaines.

In July and August, 1911, when the midstream microplankton of the river was collected at several stations between Dresden Heights and Chillicothe, specimens of septic species were nearly all *Sphærotilus natans*. In the first collections, made during the last days of July, this species was the most abundant at Dresden Heights, considerably less so at Morris, and almost insignificant in number at Marseilles, the actual figures of individual specimens per cubic centimeter of water for those three points being 186, 117, and 9 respectively. Counts of *Carchesium* and *Epistylis*, also saprobic species, were likewise much below those at Morris. A like difference in the yields of septic species between Morris and Marseilles was found in the collections of August 11 and 12 and August 23 and 24, when the average numbers per cubic centimeter were 62 and 12 for these two points respectively. This reduction in numbers down stream is probably to be understood, however, as mainly due to a mere settling out of particles carrying these organisms, and not to a change in the character of the water.

We have no exactly comparable chemical data for July; but analyses for August show oxygen ratios of 20.4 parts per million at Morris on the 11th and 11 parts at Marseilles on the 12th, and of 16.35 parts per million at Morris on the 22d and 23d and 7.4 parts per million at Marseilles on the 24th and 25th. The carbon dioxide ratios, on the other hand, were much larger at Marseilles than at Morris on these dates. Active decomposition of organic matter was thus clearly evident in this midsummer weather, at the low stage of water then prevailing. With higher water and cooler weather the differences between Morris and Marseilles were greatly diminished, the percentages of saturation February 16 to 20 standing at 48.76 for Morris and at 43.70 for Marseilles. In the fall of the following year these ratios were, in fact, reversed, the Marseilles determinations being 5 per cent. higher than at Morris September 27 and 9 per cent. higher November 14.

Alongshore July and August collections, in 1911, were similar to those at Morris, consisting mainly of *Sphærotilus natans,* rather less abundant than above, and *Stigeoclonium tenue,* found only in shallow protected places. Here also were back-swimmers (*Notonectidæ*), a few *Chironomus* larvæ, and miscellaneous oligochæte worms. A few crawfishes were captured inside or near the mouths of creeks. No Unios were seen here, either dead or alive; but a small bivalve mollusk (*Sphærium transversum*) was abundant in protected pockets along the north shore in water six inches to a foot deep, and a few living specimens of *Physa, Lymnæa,* and *Planorbis* were taken in similar situations. The bottom sludge contained at this time the same slime worms (*Tubificidæ*) as were found at Morris, as many as fifty per plate near the south shore in October, 1912.

In August and October, 1912, our more extensive collections gave us a larger list of species, of which only the most significant will be mentioned here. Besides the septic *Sphærotilus, Carchesium,* and *Epistylis,* which were less prominent than above, but still everywhere abundant, there were, at Marseilles the three blue-green algæ, *Lyngbya versicolor, Oscillatoria limosa,* and *Phormidium uncinatum,* the two latter of which are classed as pollutional and contaminate, respectively. The filamentous algæ most frequently obtained along shore were species of *Stigeoclonium, Cladophora, Spirogyra,* and *Ulothrix,* mentioned in the order of their abundance in our collections.

The organisms of the sludge, were, of course, the same as those of the preceding year. A marked difference was noticed between the chutes on the opposite sides of the island which divides the river a short distance above the falls. The current in the south chute is relatively weak, and the bottom sediments here were fine, light, and full of sludge worms; while in the strong current of the north chute the silt was denser and darker, with few or no *Tubifex.* Oligochæte worms, including naiid species, were found also in the ooze along shore, especially abundant among growths of the blue-green alga *Lyngbya.* Leeches were only occasional. There were no shore or bottom crustaceans seen at Marseilles except certain species of *Cyclops,* abundant among algæ and duckweed along the margin of the river, and a few crawfishes found only at or within the mouth of a small tributary creek. Our collections of adult insects made at this place represent fourteen genera, but the larvæ, except those of mosquitoes and horse-flies (*Tabanidæ*), found each in but one collection, were those of *Chironomus.* Both blood-red and yellow species with pupæ and unhatched eggs were obtained in twenty-one collections. No living Unios were secured either above or below the

dam, although the mussel-bar was diligently used in both places. A small bivalve mollusk, *Sphærium transversum,* was abundant along the north shore; and the univalves were much the same as at Morris. Living specimens of the following species were collected: *Lymnæa desidiosa, L. humilis, L. reflexa, L. palustris, Planorbis trivolvis, Succinea ovalis, Physa gyrina,* and *Polygyra multilineata*— the last alive in only one collection.

The yield of our fishing operations was somewhat more varied at Marseilles than at Morris, but only in the immediate neighborhood of small creeks and springs, where the water was locally or temporarily more tolerable than in the main stream. No trace of fishes was found above the Marseilles dam during July or August, 1911; and it was not until October 13 that a few minnows (*Cyprinidæ*), not identifiable at the distance, were seen near the north shore a quarter of a mile above the dam.

November 30 and December 1, 1911, hauls were made with a 120-foot minnow seine and a 150-foot one-inch mesh seine, on both the north and south shores, some three eighths of a mile above the dam; and in the vicinity of small creeks. Many young perch and shiners (*Notropis atherinoides*), a black bullhead, and a young carp were captured here at this time. None had taken food except two perch, one of which had eaten a small shiner and the other a naiid worm. February 20 to 29, 1912, two 6-foot set-nets, kept in place along the north shore, were lifted daily, a 120-foot minnow seine was hauled in water two to four feet deep, and 26 half-pound sticks of dynamite were exploded on both shores and in the mid-channel. No fish were taken in the set-nets; a single small shiner was caught with the minnow seine; and two perch and several shiners were got with dynamite. The stomachs of all were empty.

In August and September, 1912, conditions were similar to those found at Morris at the same time. Set-nets were raised every day from August 13 to 17, but without result; and a dozen half-pound sticks of dynamite were exploded, but no fish were taken. Small seines were used on the north and south shores, and the fishes thus caught, within or near the mouth of a small creek on the northern side, were as follows: black bullhead, 1; common sucker, 2; striped sucker (*Minytrema melanops*), 1 golden shiner (*Abramis chrysoleucas*), 1; bullhead minnow (*Cliola vigilax*), 12; straw-colored minnow (*Notropis blennius*), 1; young crappie, 1; rock bass, 6; pumpkinseed (*Eupomotis gibbosus*), 1; orange-spotted sunfish (*Lepomis humilis*), 1; and Johnny darter (*Boleosoma nigrum*), 4. On the night of August 19, a heavy rain, which flooded the small creeks,

washed fishes out into the river, where they became sick from sewage and could be picked up easily with a dip-net. The following morning a 3-pound carp, 2 horned dace (*Semotilus atromaculatus*), and an orange-spotted sunfish were obtained in this way. Several hauls with small seines were made October 4, but no fish were caught except a few bullhead minnows at the mouth of one of the creeks.

Below the Dam.—Turning now to the situation below the dam at Marseilles, we find that in July and August, 1911, the ratios of dissolved oxygen three fourths of a mile below were more than three times as great as those just above*; that under winter conditions in February and March they were 13 and 14 per cent. greater; and that in August and September, 1912, with cooler weather and higher river levels than in the previous year, they varied from one and a half to two times as great. The necessity of taking samples for analysis at some distance below the fall was shown by the fact that the oxygen content of the water September 1, 1911, an eighth of a mile below, was more than ten times that above—a discrepancy to be accounted for only on the supposition that the air mechanically caught in the water at the fall had not yet had time to escape. The water below the fall in 1911 was visibly cleaner than that above, and there was less *Sphærotilus natans* in the plankton collections. This was probably due in part to sedimentation in the slack water above the dam, and in part to the pulverization of the coarser organic particles by the pounding of the water at the fall.

We were told by observant residents, in 1911, that fishes usually come up to Marseilles in some variety—bass only in the highest water, but carp in both summer and winter of every year; but none of either were seen or heard of there in July and August of that year. Strings of black bullheads were being caught below the dam October 13, 1911, and carp were said to have been common there since the fall rains began. Our winter fishing with set-nets and dynamite was, however, no more productive than at Morris. Small nets set in February, 1912, from one hundred to two hundred yards below the dam, near the north shore, caught only two shiners, and were then destroyed by floating ice; and six sticks of dynamite, exploded from a half to three quarters of a mile below the dam, gave us only two more of the same species. The stomachs of all these fishes were empty.

August 14 and 15, 1912, we found essentially the same conditions as to fishes below the dam which were found above, except that we

*It was impossible to reach the center of the stream here, and samples were taken from the stern of a skiff fifteen feet from the north shore, in water two feet deep. The current at low water, July 31, was estimated at five miles per hour.

got a greater variety of species in shallow water along shore near the mouths of small tributaries. From the full current of the river only a dozen specimens of a shiner (*Notropis atherinoides*) were captured, and these by dynamite explosions, the set-nets coming up empty. By the use of small seines and dynamite we obtained in shallow water along shore examples of the species shown by the following list.

FISH COLLECTIONS, BELOW THE DAM, MARSEILLES, AUGUST 14 AND 15, 1912

	River; full current. Dynamite	River, near mouth of small creek. Dynamite	River, near mouth of spring rivulet. Seine	Small creek, within mouth. Seine	Totals
Common sucker		2	6	7	15
European carp		2	1	2	5
Red-bellied dace (*Chrosomus erythrogaster*)			1	1	2
Blunt-nosed minnow (*Pimephales notatus*)			2	1	3
Horned dace			6	1	7
Golden shiner		1			1
Straw-colored minnow (*Notropis blennius*)			1	1	2
Notropis gilberti			1		1
Silverfin (*Notropis whipplii*)		1			1
Shiner (*Notropis alherinoides*)	12				12
Sucker-mouthed minnow (*Phenacobius mirabilis*)			1	1	2
Black-nosed dace (*Rhinichthys atronasus*)			14	15	29
Black bullhead		2			2
Pumpkinseed		1			1
Rainbow darter (*Etheostoma cœruleum*)				1	1
Totals	12	9	33	30	84

A comparison of the fourth column with the others preceding makes it probable that most of the specimens taken from the river here were migrants from the creeks, and if not it is certain that the creek waters along shore were being commonly sought by them. A notable exception is the abundant shiner (*N. atherinoides*), which we shall find the commonest fish in our river collections all the way to Chillicothe.

The microplankton was, as might be expected, virtually the same as above, except that the number of organisms per cubic centimeter was only about four fifths as great below, possibly because many of

the more delicate of the *Protozoa* were killed by the pounding of the falling water. Univalve mollusks were not only living, but were breeding here August 25; whirligig beetles—mostly *Gyrinus analis*—were common; large isopod crustaceans—*Asellus*—were taken here for the first time; and a few slime worms (*Tubifex*) were found where soft mud was deposited in sheltered places, the current being too swift for any considerable accumulation of bottom sediments.

In respect to organisms of other classes, the differences above and below the dam were merely trivial, unless we may attach some importance to the fact that our first specimens of the bryozoan *Plumatella repens*, were taken below. This species was not found above Marseilles, but occurred regularly at the various stations from that point downward.

Ottawa

No collections were made at Ottawa in 1911; and the several oxygen determinations of September 2 of that year are of little use for comparison, since the samples were all taken near the south shore above the mouth of the Fox River, from only six inches below the surface, in water but two feet deep. They averaged 5.34 parts per million, or 63.1 per cent. of saturation. The carbon dioxide on this date varied from 4.2 to 5.5 parts per million, with an average of 4.66.

August 22, 1912, oxygen tests from each side of the river above the Fox, averaged 3.65 parts per million. November 2 the water of the Illinois above the Fox gave 5.7 parts per million; and that of the Fox itself nearly twice as much (11.2 parts per million).

In 1912, biological collections were made here for seven days, August 22 to 28 inclusive. Dip-nets, small seines, dredges, the mussel-bar, and dynamite, were variously used, according to the situation and the object in view. The water at this time had a distinct sewage odor, somewhat less noticeable, however, than at Marseilles, and among the weeds along the banks was an oily, tar-like scum similar to what had been noticed in the sanitary canal at Lockport. It apparently originated in gas-house wastes. Other more or less recognizable objects from the sewage were more abundant here along shore than usual, possibly because a heavy rain which had fallen three days before, bringing the river up about a foot, had flushed out the Des Plaines.

The river sludge obtained at various points did not differ appreciably from that above, either in sensible character or in organisms contained, except for the occurrence of a few living snails and speci-

mens of the bivalve mollusk *Sphærium*, found in a somewhat sandy deposit two hundred yards below the Ottawa wagon-bridge. The characteristic foul-water organisms, *Sphærotilus, Carchesium,* etc., although common in weeds along the edges of the stream, and obtained also from the current, were less abundant than at Marseilles. The same blue-green and filamentous green algæ found at Marseilles were collected here also. There were no sponges, hydroids, or planarians; but leeches occurred now in fourteen collections. *Cyclops* was found among the marginal algæ, as above, and a single isopod crustacean, *Asellus,* was taken in the drift on the south shore.

The lessening of contaminate conditions was especially shown by the occurrence of small numbers of various insect larvæ, including those of dragon-flies, caddis-flies, and May-flies (*Cœnis* and *Hexagenia*), and pupæ of the sand-fly (*Simulium*). Larvæ and pupæ of *Chironomus* were obtained in twenty-two collections. Diligent use of the crow-foot dredge in various situations brought to light no living mussels except on a bar in Fox River water just outside the mouth of that stream. Here two species were obtained alive—*Lampsilis ventricosa* and *L. lævissima*—and dead shells of eight other species. One large specimen of *Anodonta corpulenta* had quite recently succumbed, the flesh being not yet decayed.

Species of univalve mollusks, taken largely by the Ekmann dredge from the bottom of the main stream, became at this point rather too numerous for special mention in a preliminary report. *Planorbis trivolvis* and *Physa gyrina* were the most abundant, and a species of *Amnicola* next. The number of dead shells of both Unios and univalves, as compared with the living specimens found, was indicative of an environment still difficult for mollusks.

Our fish collections at Ottawa were made August 26 and 27, 1912, with small seines and dynamite. They aggregated one hundred and twenty-five specimens, representing seventeen species, of which forty-six specimens belonging to fourteen species were from Fox River water just outside the mouth of that stream. From the water of the Illinois itself, we have the following six species: 1 carp, 1 black bullhead, 1 red-horse, 2 blunt-nosed minnows, 2 horned dace, and 69 shiners, 18 more of the last coming from the Fox River water. The seines gave us fifty-eight specimens of fifteen species; and the dynamite explosions, sixty-seven specimens of six species. Only two of the latter, the carp and the horned dace, were secured by dynamite which did not also come out in the seines. The following is the complete list.

FISH COLLECTIONS AT OTTAWA, AUGUST 26 AND 27, 1912

	Illinois River, near mouth of Fox. Seines	North shore, above Fox. Seines	North shore, between bridges. Seines	Half mile below C. B. & Q. bridge. Dynamite	South shore, above Fox. Dynamite	South shore, one mile below C. B. & Q. bridge. Dynamite	South shore, near lower end of city. Dynamite	Totals
Gizzard-shad *Dorosoma cepedianum*	1	1		1				3
Quillback *Carpiodes velifer*	6							6
Chub-sucker *Erimyzon sucetta oblongus*	1							1
Common red-horse *Moxostoma aureolum*	2			1				3
European carp				1				1
Blunt-nosed minnow *Pimephales notatus*	4			1	2			7
Horned dace *Semotilus atromaculatus*					2			2
Bullhead minnow *Cliola vigilax*	1							1
Straw-colored minnow *Notropis blennius*	3							3
Silverfin *Notropis whipplii*	2							2
Shiner *Notropis atherinoides*	18		10	29	23	2	5	87
Black bullhead *Ameiurus melas*		1						1
Orange-spotted sunfish *Lepomis humilis*	1							1
Bluegill *Lepomis pallidus*	1							1
Pumpkinseed *Eupomotis gibbosus*	3							3
Small-mouthed black bass *Micropterus dolomieu*	2							2
Large-mouthed black bass *Micropterus salmoides*	1							1
Totals	46	2	10	33	27	2	5	125

From a comparison of the first column of this table, showing the collections taken from the shallow water near the mouth of the Fox, with the other columns, it is plain that Fox River water was greatly preferred by fishes at this place, and it seems likely indeed, that most of the specimens taken at this point had come into the river from the Fox itself. The common shiner is, as usual, a notable exception, this abundant lake and river minnow being unusually tolerant of polluted waters.

Starved Rock

The odor of the water at Starved Rock, August, 1911, was still disagreeable, but there were no bubbles of gas from the bottom, and there was sensibly less suspended matter in the water than at Marseilles. North of the island the stream was perceptibly cleaner and of a greener color than in the south channel, probably because it carried a larger admixture of Fox River water, with its greener plankton. The surface temperature of the water was 78° F. August 15, and 72° August 26. The effect of Fox River contributions to the Illinois was plainly manifest by an average difference of 21 per cent. between the oxygen ratios of the two sides of the Illinois, as shown by seventeen sets of tests made August 15 and 26, 1911, and February 23, August 22, September 6 and 28, and October 11 and 26, 1912. The lowest ratio of the series was 2.5 parts per million from the south shore, September 6, 1912, and the highest was 5 parts per million, also from the south shore, October 26. The general average for the south shore was 3.23 parts per millon (35.9 per cent. of saturation), and that for the north shore, with its larger admixture of Fox River water, was 3.91 parts per million (43.6 per cent. of saturation).

The only sewage organisms found were isolated filaments or minute tufts of *Sphærotilus natans* floating in the current. Minnows, identified as golden shiners and spot-tailed minnows (*Notropis hudsonius*) were seen swimming near the surface on both sides of the river. This is the first observation of the second of these species. An old resident of the town informed us that a considerable variety of fishes is to be found here, practically at all times, but that the numbers are never large.

In 1912, collections were made at Starved Rock September 3 and 9 and October 9 to 11. The water had still a slight sewage odor, but less than at Ottawa. *Sphærotilus* and *Carchesium* were occasionally seen attached to weeds and grass at the edge, and moderate

numbers of small particles composed of them were floating down stream. Samples of sludge obtained at this time were full of slime worms, as usual, those from the chute on the north side of the island averaging a hundred per plate, and those from the south side twice as many. In the north chute were also many living snails, especially *Campeloma* (which was very abundant) and a much smaller number of *Physa* and *Pleurocera*. The sludge collections from the south shore contained some *Campeloma*, but none of the other snails. In the channel below the island the current was too swift to permit the deposit of a fine sediment, and the bottom was sandy, with dead snails only. The only blue-green algæ were a *Lyngbya* and a *Phormidium*, taken in three collections, while filamentous green algæ occurred in thirty-seven. The most abundant forms were *Cladophora*, both *crispata* and *glomerata*, and *Stigeoclonium tenue* and *lubricum*. Living sponges were obtained on dead mussel shells in three collections.

The isopod *Asellus* was common in dredge hauls and among the algæ at the edge. Crawfishes were taken here in two collections, and *Chironomus* larvæ and pupæ in seventeen. The situation was not productive of Unios, and but two species were taken alive—*Quadrula plicata* and *Symphynota complanata*. Five collections contained both dead and living *Sphærium transversum*, and four contained living *Ancylus*. Statoblasts of *Plumatella* were abundant in the drift, and other *Bryozoa* were common on shells of dead and living mussels.

Our fishing at this point was mainly done September 3, between Starved Rock and the mouth of the Vermilion. A quarter of a mile below the landing, on the north shore, at the mouth of a creek, a dynamite explosion gave us a blunt-nosed minnow, many shiners, a *Notropis jejunus*, a large-mouthed black bass, and a gizzard-shad. A half-mile below, dynamite and a 60-foot seine yielded a very large number of shiners, three silverfins, a golden shiner, and a short-headed red-horse (*Moxostoma breviceps*). A haul of the 60-foot seine on "Little Rock bar" near the south shore brought in several hundred young carp from two to five inches long, a great abundance of shiners, and a black bullhead. A haul in the channel with a 200-yard seine with an inch mesh, on the other hand, brought in no fish. A dynamite explosion near the south shore, three quarters of a mile above the mouth of the Vermilion, brought to the surface three 2-pound carp and many shiners. Additional dynamite explosions made September 3 and 4 at five different points down the river as far as Spring Valley, gave us large numbers of the shiner (*Notropis atherinoides*), but no other specimens except a 3-inch carp and four golden shiners.

From the following complete list, compared with that made at Ottawa, it seems that the fishes taken here represented the normal river stock at this place, with practically no immediate admixture from small tributary streams.

1 Gizzard-shad (*Dorosoma cepedianum*).
3 Carp, adults, and several hundred young.
1 Short-headed red-horse (*Moxostoma breviceps*).
1 Blunt-nosed minnow (*Pimephales notatus*).
5 Golden shiner (*Abramis chrysoleucas*).
3 Silverfin (*Notropis whipplii*).
1 *Notropis jejunus.*
Very many shiners (*Notropis atherinoides*).
1 Black bullhead (*Ameiurus melas*).
1 Large-mouthed black bass (*Micropterus salmoides*).

La Salle-Peru

In August, 1911, the water at Peru had still a grayish look, was full of very minute grayish particles, and had a slight sewage odor, more pronounced near the northern side, partly, no doubt, because of sewage entering the stream at La Salle and Peru. The presence of Vermilion River water on the south side probably increased this difference. The water temperature August 2, was 72° F. The only collections made, besides those of fishes reported above, were mussels obtained in 1912 by the use of the mussel-bar. Thirty-six specimens, representing ten species, included twelve living specimens of five of the species only, namely, *Lampsilis alata, L. ligamentina, L. gracilis, Quadrula plicata,* and *Symphynota complanata.* The large proportion of dead specimens, as compared with the ratios obtained farther down the stream, indicate unfavorable conditions for mussels in the stretch of river between Utica and Peru. The following is a complete species list.

Species	Alive	Dead
Lampsilis alata	1	4
L. gracilis	1	1
L. ligamentina	4	3
L. ventricosa		4
Obliquaria reflexa		1
Quadrula ebena		1
Q. plicata	5	3
Q. pustulosa		1
Quadrula sp.		3
Strophitus edentulus		1
Symphynota complanata	1	2
Totals	12	24

The only chemical tests at this place were made August 2, 1911, and July 11 and November 15, 1912. August 2, the oxygen ratios opposite Peru varied from 3.17 to 3.51 parts per million (35.8 to 39.6 percentages of saturation), according to the place in the river from which the samples were taken. A carbon dioxide test of water taken from near the south side of the stream under the bridge gave 6.6 parts per million.

July 11, 1912, the oxygen in the river at Peru was lower than in the preceding August—2.7 parts per million, equivalent to 32.2 per cent. of saturation at the temperature of the time. November 15, on the other hand, the oxygen ratio was 8.9 parts per million—71.3 per cent. of saturation. As the old Illinois-Michigan Canal opens into the Illinois River at La Salle, it was a point of interest to know the character of the water which it was adding to the stream at that place. July 11, 1912, the oxygen ratio within the mouth of the canal was 4.31, and November 15 it was 9.7—the former 51 and the latter 75 per cent. of saturation. Local contaminations by sewage, gas wastes, and wastes of the zinc works were disturbing elements at La Salle, the situation being further complicated by the inflow of uncontaminated water through the Vermilion, a short distance above on the opposite side of the Illinois, and the station was consequently dropped in 1912.

Spring Valley

July 11, 1912, there was decidedly less oxygen in the water at Spring Valley than at Peru—1.95 parts per million, as compared with 2.7 parts, the water temperatures being 77° F. at both points.

November 15, however, the oxygen ratios were precisely the same—8.9 for each. The loss of oxygen down stream in July was perhaps due to a rapid hot-weather decomposition of sewage materials received at Peru and La Salle.

Our only collections at Spring Valley were made with dip-nets, dredges, and small seines October 15 to 18, 1912. The water, even this far down the stream, had a noticeable sewage odor and a grayish color, with no tinge of green; but it improved greatly before reaching Hennepin, where it was odorless and of a greenish hue. The bottom sludge changes more slowly, however, as one goes down stream, and samples taken October 18 a quarter of a mile below Spring Valley in water twelve feet deep were still swarming with *Tubifex*—several hundred to the plate. At Spring Valley the weeds and grass at the edge of the river were free from *Sphærotilus* and *Carchesium*, and these sewage organisms were not taken in the plankton. No blue-green algæ were found here except a small quantity of *Lyngbya versicolor;* and the green filamentous algæ were mainly *Cladophora crispata* and *Stigeoclonium tenue*, with some *Ulothrix*, *Oscillaria*, and *Vaucheria*. Sponges were found on the mussel shells; leeches occurred in eight of the collections; *Cyclops* was abundant in the algæ; and shells of five species of mussels were dredged from the bottom—all dead, however, except one specimen of *Quadrula pustulosa*. Among the other living mollusks were many *Campeloma*, *Planorbis trivolvis*, *Sphærium transversum*, *Pisidium*, and *Ancylus;* and a few other species were represented by dead shells. *Plumatella repens* was common on logs.

Depue

Similar collections were made October 17 and 18, 1912, from the Illinois River, opposite Depue Lake. The sludge at this point was less offensive than above, and contained but fifty specimens of *Tubifex* per plate. Three of the collections contained the isopod crustacean *Asellus*. *Ostracoda* were in the duckweed along shore, together with the crustacean *Hyalella knickerbockeri*, the first to occur in these river collections below Lockport. Here also was taken the first specimen of the common river shrimp, *Palæmonetes exilipes*. Caddis-fly larvæ were abundant on mussel shells, and dragon-fly nymphs were taken in five collections. Six species of mussels—*Quadrula heros*, *Q. plicata*, *Q. pustulosa*, *Q, asperrima*, *Anodonta grandis*, and *Tritogonia tuberculata*—were represented by living specimens taken in a small dredge. *Succinea*, *Campeloma*, *Planorbis*,

Sphærium, Pisidium, and *Ancyclus* were all abundant, as was also *Plumatella repens* on sticks and logs.

In Depue Lake itself dip-nets, dredges, and small seines yielded many common worms not found above, naiids, planarians, etc., and *Hyalella knickerbockeri* was abundant among algæ, in all situations. Insect larvæ were likewise present in unusual variety, including *Chironomus* and *Ceratopogon* larvæ, larvæ of caddis-flies and May-flies (*Cœnis* and *Callibœtis*), tipulid larvæ, and larvæ of several species of larger dragon-flies and damsel-flies (*Agrioninæ*). Among the mollusks were *Quadrula undulata, Q. plicata, Vivipara contectoides, Lioplax, Sphærium transversum,* and *Ancylus,* besides a number of species represented only by dead shells. Fishermen believe that the poisonous wastes from the Depue zinc works are killing the shells on the bottom of this lake. It was here that the first commercial fisheries were encountered; and a haul made at the foot of Depue Lake October 18, yielded about two hundred pounds of carp and a hundred pounds of sunfish and crappies.

Hennepin to Henry

At Hennepin the water became to all appearance practically normal, even in the midsummer of 1911, being odorless, greenish with phytoplankton, and free from suspended clusters of foul-water organisms and particles of sewage debris. Here we found commercial fishing in progress in both the river and the adjacent lakes, mainly, however, in the latter. Mud taken in September from the bottom of the channel at Hennepin was more sandy than above, had no offensive odor, contained many snails—*Campeloma, Pleurocera,* etc., many specimens of *Sphærium transversum,* and only a moderate number of slime worms. Similar materials were obtained from the bottom at the Henry dam, except that the sediments in the sluggish current there were softer, finer, and darker than in the full flow of the stream at Hennepin. At the low temperatures of March, 1913, however, the sludge was offensively corrupt much farther down the stream than in the warmer season, as will be more fully explained under the next section. The midsummer microplankton of 1911 confirmed the other lines of evidence, yielding but 2 septic organisms to the cubic centimeter as compared with 16 at Starved Rock and 80 at Morris; and 6 pollutional forms as compared with 7 at Chillicothe below, 71 at Starved Rock, 134 at Marseilles, and 142 at Morris. Forms classed as contaminate, on the other hand, were more numerous both here and at Chillicothe than above, and clean-

water forms were 138 to the cubic centimeter at Hennepin, 744 at Chillicothe, and 154 at Marseilles, as compared with 193 at Morris. Oxygen ratios were a little lower in July, August, and September than at Starved Rock, and somewhat higher in October and November.

As this was the first station at which the life of the river may be said to have found virtually normal conditions, some further testimony to that effect may be drawn from our collections of mussels and fishes. Seventeen species of mussels were collected alive, and five others were represented only by dead shells. Of these *Lampsilis fallaciosa, Quadrula plicata, Symphynota complanata, Anodonta corpulenta,* and *Quadrula heros* were the most abundant, in the order named, and, with a single exception, all the specimens of these species were alive. The number of living shells as compared with dead ones is in marked contrast to the conditions found above. The following is a complete list.

HENNEPIN, 1912

Species	Alive	Dead
Alasmodonta confragosa	1	1
Anodonta corpulenta	14	
A. grandis		1
A. imbecillis	1	
Anodontoides ferrussacianus	1	
Lampsilis alata	5	
L. fallaciosa	60	
L. gracilis	10	1
L. lævissima	2	
L. ligamentina	1	4
L. luteola	8	4
L. occidens		1
L. parva	1	
L. ventricosa		2
Quadrula asperrima	2	1
Q. heros	11	3
Q. plicata	45	
Q. pustulosa		2
Q. trigona	1	1
Q. undulata		1
Strophitus edentulus	1	
Symphynota complanata	23	1
Totals	187	23

The following fishes were taken September 6 and 13 from the river in the vicinity of Hennepin, by seven hauls of a 30-yard minnow seine, 15 hauls with a 200-yard seine with an inch mesh, and a single haul made for us by a fisherman with a common river-seine.

Hennepin, 1912

Short-nosed gar, 1
Dogfish, 3
Common sucker, 1.
European carp, 174.
Shiner, many.
Golden shiner, many.
Speckled bullhead (*Ameiurus nebulosus*), 1.
Black bullhead, 1.
Black crappie (*Pomoxis sparoides*), 1.
Warmouth (*Chænobryttus gulosus*), 1.
Blue-gill sunfish, 3.

The weather was very hot when the larger seines were used, ranging above 90° F. every day, with the water at 79°, and the fishing was unusually poor.

Henry to Chillicothe

As this is the final section of our series, a fairly full description of conditions found and collections made will be desirable for comparison. Even under the midsummer conditions of July and August, 1911, with the river temperatures at 73° to 80° F., the water had a distinct greenish cast, without odor; and mud taken from the bottom had a "good fresh smell." In March, 1913, however, the sludge from a deposit two feet deep a hundred yards above the Henry dam had a distinct sewage odor, and was destitute of animal life, except for one small leech, in nine two-quarts samples collected. The cooler temperature of the water (41° F.) delayed decomposition, and the comparatively strong current of the stream at the high water of this visit (10 feet at the upper gage) was doubtless rolling the bottom sediments more rapidly down the stream than in the lower stages at which our earlier observations were made. Practically the same may be said of the condition of the bottom mud from the main channel at Chillicothe at this time. The river was, however, still far below a normal unpolluted stream in oxygen ratios, and contained much more carbon dioxide. A number of tests of midstream samples made August 3 and August 29, gave us 2.33 parts per million of oxygen as a minimum and 4.59 as a maximum, with an average of 3.76 for nine determinations. Carbon dioxide ratios for this period ranged from 4.9 to 6.9 parts per million.

A heavy flooding rain which fell August 10 had the effect to

bring the oxygen ratios down, doubtless fouling the stream by flushing out sewers, scouring out tributary streams, stirring up the bottom sediments, and washing off organic debris from the surface of the country. The oxygen mean for August 3 and 4 was 4.21, and that for August 17 was 2.35, the corresponding carbon dioxide ratios being 5.8 for the first dates and 6.8 for the last.

November 8, 1911, the oxygen stood, at Chillicothe, at 10.15 parts per million, equal to 84 per cent. of saturation. Our lowest reading at this place came in July, 1912, on the 12th of which month there were but 2.05 parts per million of oxygen at Chillicothe—less than 24 per cent. of saturation. In the cooler weather of the following October and early November, with moderately high water. the ratios rose to an average of 7.5 parts per million (64 per cent. of saturation).

Between Hennepin and Chillicothe the difference in dissolved gases was but slight, and the plants and animals were virtually those of the normal population at both places and on all our visits. Our systematic collections here were made November 7, 1911, September 18 and 19, 1912, and October 22-25 of the same year. As the collections of the second year were much more detailed and extensive than those of the first, no especial account of the latter need be given.

September 18 and 19, the mussel-bar and dredges were used at various points below Henry and above Chillicothe; and October 22-25, work was done in the vicinity of Chillicothe only, with dip-nets, dredges, and small seines, no large seines, set-nets, or dynamite being brought into use at these lower stations. The river gage above the dam at Henry stood at 3.4 to 3.6.

Four hundred and ten collections were made from this section, of which 159 contained mollusks, 91 contained adult insects and insect larvæ, 42 contained *Crustacea,* and 18, fishes. Blue-green algæ were found in 10 of the Chillicothe collections—chiefly *Oscillatoria limosa* and *splendida*—usually, however, on boards and logs afloat along the edge of the stream. *Cladophora crispata* and *glomerata* were the most abundant filamentous green algæ, *Stigeoclonium tenue* and *Spirogyra decimina* var. *triplicata* coming next. Duckweed (*Lemna* and *Wolffia*), hornwort (*Ceratophyllum*), and *Elodea* were abundant higher plants. Sponges were found, as usual, on dead and living mussel shells. Oligochæte worms were rare in the bottom dredgings, as compared with those made above; planarians were occasional, and leeches occurred in fifteen collections. Of the crustaceans taken, the little "side shrimp" (*Hyalella knickerbockeri*) was

the most abundant, among algæ near the shores; *Asellus* was also common at the margin; and the river shrimp (*Palæmonetes*) and crawfishes were frequently taken. The aquatic insects occurring here were as follows:

Adults: *Gyrinus analis, Tropisternus dorsalis, T. glaber, Peltodytes edentulus, P. pedunculatus, Coptotomus interrogatus, Dryops lithophilus, Philhydrus nebulosus, Colymbetes sculptilis, Notonecta variabilis, Corixa erichsoni, C. burmeisteri; C. alternata, C. harrisii, Mesovelia mulsanti, Zaitha fluminea, Pelocoris pocyi, Ranatra fusca.* Larvæ: agrionid nymphs, *Mesothemis simplicicollis, Anax junius* (nymph), *Celithemis* nymphs, *Odontomyia, Chironomidæ,* caddis larvæ, *Chauliodes.*

Our mussel collections, representing twenty-two species, were very like those at Hennepin, differing in the addition to the Hennepin list of *Lampsilis anodontoides, Obliquaria reflexa, Plagiola elegans, P. securis, Quadrula ebena, Tritogonia tuberculata,* and *Unio gibbosus.* Among the most abundant species were *Anodonta imbecillis, Lampsilis fallaciosa, Quadrula heros,* and *Q. plicata. Sphærium transversum* was also common here, with occasional specimens of *S. striatinum* and *S. jayanum. Pisidium* was taken in four collections with the Ekmann dredge, in water six to eight feet deep.

The commonest snails were *Campeloma* and *Vivipara contectoides,* both very abundant in various situations, and *Pleurocera,* obtained mainly by the Ekmann dredge at depths varying from six to thirty feet. Additional species are *Physa gyrina, Planorbis trivolvis, P. parvus, Valvata bicarinata, Lioplax, Goniobasis,* and *Ammicola.*

Commercial fishing is carried on in the Henry-Chillicothe section on a large scale in good seasons, but much complaint has lately been made, all along this part of the river, that fishing is not so good as in former years. No systematic work for the collection of fishes was done, and the only specimens taken were caught in small seines used for collecting shore invertebrates, and are as follows:

Golden shiner, 1.	Fundulus dispar, 8.
Spot-tailed minnow, 3.	Warmouth sunfish, 1.
Silverfin, 1	Blue-gill sunfish, 7.
Shiner, 61	Large-mouth black bass, 2.
Top-minnows (young), 2.	Yellow perch, 1.

This list should be combined with the list for Hennepin to give a fair idea of our collections from this section of the river at this time, those from Hennepin having been made wholly with large seines.

We have secured further information concerning the present status of the more important fishes in this part of the upper Illinois by inquiry from reliable, experienced, and unusually well-informed fishermen of our acquaintance, especially from Herman Mehl and A. C. Wilkey, of Chillicothe, Peterman Brothers and Herbert Hall, of Henry, and F. L. Powers, for twenty-seven years a fisherman at Depue, and the following list is made up from their personal statements to us.

STATUS OF PRINCIPAL FISHES, UPPER ILLINOIS RIVER, CHILLICOTHE, HENRY, AND DEPUE, APRIL, 1913

(Statements as to numbers relate to the river only, except where otherwise specified)

Fishes	Chillicothe	Henry	Depue
Shovel-nosed sturgeon	Never taken now	Never taken now	None seen for years.
Paddle-fish	Very few; none this year	Very few; none this year	None seen for 6 or 7 years past.
Dogfish	About as numerous as ever	Becoming scarcer	Few.
Short-nosed gar	As numerous as ever	As numerous as ever	Common, but less numerous than formerly.
Long-nosed gar	As numerous as ever	As numerous as ever	Common, but less numerous than formerly.
Mud-cat	Very rare	None	None.
Channel-cat (*Ictalurus punctatus*)	Becoming scarce	Becoming scarce	Now rare; 15 years ago were taken by the ton.
Blue cat (*Ictalurus furcatus*)	None at all	Very rare or none	None taken for years.
Bullhead; 3 species	About as formerly	Not so many as formerly	Much less common than formerly; yellow bullhead now most abundant.
Common sucker	Very few	Not many	None at all.
Missouri sucker	Hardly ever seen	One this spring	None at all.
Red-horse (*Moxostoma;* various species)	Very rare	Very rare	Gone entirely; taken by the ton 15 or 20 years ago.
Native carp (*Carpiodes;* various species)	Not many	Not many	Only a few.

STATUS OF PRINCIPAL FISHES, UPPER ILLINOIS RIVER—*Continued*

Fishes	Chillicothe	Henry	Depue
Buffalo (*Ictiobus*; 3 species)	Increasingly rare	Almost gone; red-mouth the most commonly taken; less than 50 lbs. to 1000 lbs. of carp	A few red-mouth only; 8 years ago 500 lbs. of buffalo were taken in a haul of 37,000 lbs. of fish from Depue Lake, the remainder being carp; now nets in the river and lake get hardly 5 lbs. of buffalo to the thousand pounds of carp.
Eel	Very few	None	None for years.
Gizzard-shad	About as common as ever	Probably less common than formerly; now being sold for food	Not so many as formerly.
Pike	None	None	All gone.
Bluegill	About as usual	Much less common than formerly	Supply diminished greatly in last ten years.
Pumpkinseed	Scarce	Scarce	None.
Goggle-eye (*Chænobrytus gulosus*)	Not as many as formerly	A good many	Rare.
Black crappie	Rarer than formerly	Few	Very rare; now hardly a pound where a ton was taken 15 or 20 years ago.
Pale crappie	A good many at times	Less common than in previous years	A few; now hardly a pound to a ton taken 15 or 20 years ago.
Large-mouth black bass	More abundant than a few years ago	Decreasing numbers in last 3 years	Fewer than formerly.
Common perch	About the same as previously	About the same as previously	Hardly enough for a mess of fish taken all the season.
Wall-eyed pike	None	Very rare	None.
Striped bass (*Roccus chrysops*)	Usually a few only	A good many at times	But few.
Sheepshead	Hardly any; none at all this year	Rare; none at all this year	None now taken.

It should be said, with respect to the present scarcity of several of these species as compared with previous times, that the causes are probably complex, and are not to be sought in differences of the water only. As has been shown in another place*, a great stimulus to fishing operations, due to an enormous multiplication of European carp, may well have had the effect to reduce the numbers of many native species whose haunts and habits are such that they are likely to be caught by the same apparatus and operations as the carp.

A comparison of this account of Chillicothe conditions and collections with those for Morris and for Marseilles above the dam will show the main features of the effects of a sewage pollution of the river and the completeness of the biological, if not the chemical, recovery within ninety miles below.

Summary by Stations

The Sanitary Canal at Lockport.—Although the water of the canal at Lockport was comparatively clear, with an inoffensive odor even in August and September, 1911, it was not only rather heavily loaded with putrescible materials from Chicago sewage, mainly as yet undecomposed, but it was lower in oxygen content at most times than the river water either of the Des Plaines or the Illinois at any point where our tests and collections were made. In the winter however, the amount of oxygen in solution approximated the ratios of an unpolluted stream, being actually higher in February, 1912, than at any point between Lockport and Peoria. This is to be understood, of course, as due to the gradual start and slow development of the self-purification process in cold weather. Many small fishes came down the canal in summer and fall, mostly dead when they reached Lockport, although many "shiners" were still alive, but in a dying state. There were no living snails, crustaceans, or water-breathing insects in the water or on the bottom, and except for a few green algæ and other minute organisms on the riprap at the edges, the plants and animals were those of a polluted stream. These were, however, very much less abundant here in summer than in the Des Plaines beside the canal, or in the main river below.

The Des Plaines River at Lockport.—The condition and contents of the Des Plaines at Lockport, where the stream runs beside the sanitary canal, vary greatly with varying circumstances—local, seasonal, or merely meteorological. In the summer of 1911, the whole

*"The Native Animal Resources of the State." Stephen A. Forbes. Trans. Fifth Ann. Meeting, Ill. State Acad. Sci., pp. 42-43.

stream at this point was carrying polluted water, and sewage organisms were abundant across the bottom and on both sides— a fact to be attributed in part, according to our best information, to contributions of sewage from the towns above. In August and September, 1912, however, the two sides of the Des Plaines were in marked contrast. On the west side were minnows, sunfishes, green algæ, case-worms, sand-fly larvæ, *Entomostraca, Hyalella knickerbockeri,* and several kinds of mollusks, while on the east side *Sphærotilus, Carchesium, Vorticella microstoma,* and numerous other sewage organisms predominated, with fishes and clean-water mollusks conspicuous by their absence.

The Des Plaines River at Dresden Heights.—The Des Plaines at its mouth was heavily loaded with putrescible sewage materials so far advanced in decomposition that oxygen ratios were always very low. They differed however, according to season, in comparison with those of the next lower stations, being higher than these in the hottest weather and lower at lower temperatures. In July, 1911, for example, when the water of the Des Plaines contained 1.21 parts per million, that of the Illinois stood at 1.07 at Morris, and at .83 above the Marseilles dam. In November, 1912, on the other hand, the corresponding figures were 4.90 for the Des Plaines, 6.80 for the Illinois at Morris, and 7.90 at the Marseilles dam. This seasonal difference is again to be accounted for by the different effect of low and high temperatures upon the beginning and rapidity of the decomposition process in a polluted stream.

The plants and animals of the Des Plaines being of a diverse origin, were a mixture of clean-water forms from the lake and from the upper river which had not yet been overcome by their septic environment, and of species characteristic of polluted water, the latter group strongly dominating. Saprobic organisms of the midsummer microplankton were more numerous here than at any point on the river; but mingled with these were many Lake Michigan diatoms, some of which presently disappeared down stream, two continuing, however, to the lower river, where they became very abundant beyond the heavily polluted section.

There were no fishes, mollusks, crustaceans, or insect larvæ (except *Chironomus*) in the Des Plaines at Dresden Heights, although the Kankakee, but a few rods away, contained the usual biological population of a normal Illinois river.

The Kankakee at its Mouth.—Notwithstanding the fact that the Kankakee can hardly be called an uncontaminated river, its contrast with the Des Plaines, especially in summer, was very marked. When

the water of the latter stream at its mouth contained but 1.21 parts of oxygen per million, the ratio for the Kankakee was 11.21; and when the oxygen in the Des Plaines rose to 4.90 in November, that of the Kankakee was 10.90. Our lowest reading for the latter stream was 9 parts per million, in February, when the Kankakee was mainly covered with ice. Most of the oxygen ratios in the Kankakee were above those which the water will absorb directly from the air, and indicated a "supersaturation" varying from 105 to 133 per cent.

The differences between the two waters thrown together at the origin of the Illinois were reflected in oxygen ratios from the two sides of the stream just below the junction, as reported November 14, 1912—4.6 parts per million for the water of the northern or Des Plaines side, and 11.3 parts per million for the water of the southern or Kankakee side.

Morris to Marseilles.—In the seventeen-mile section of the Illinois from Morris to the upper dam the river reaches its lowest point of pollutional distress, becoming, when very hot weather coincides with a low stage of water, a thoroughly sick stream. Its oxygen is nearly all gone; its carbon dioxide rises to the maximum; its sediments become substantially like the sludge of a septic tank; its surface bubbles with the gases of decomposition escaping from sludge banks on its bottom; its odor is offensive; and its color is gray with suspended specks and larger clusters of sewage organisms carried down from the stony floor of the polluted Des Plaines, or swept from their attachments along the banks of the Illinois. On its surface are also floating masses of decaying debris borne up by the gases developing within them, and covered and fringed with the "sewage fungus" (*Sphærotilus natans*) and the bell animalcule (*Carchesium lachmanni*) usually associated in these waters. The vegetation and drift at the edge of the stream are also everywhere slimy with these foul-water plants and minute filth-loving animals. The two sides of the stream differ materially in condition at Morris, and sometimes also at Marseilles, the waters of the Kankakee and the Des Plaines not becoming completely mingled until they have passed these points.

The normal life of the stream practically disappears in the absence of oxygen; its fishes withdraw to neighboring unpolluted waters; its mollusks, crustaceans, ordinary insect larvæ and other more or less sedentary forms disappear to be replaced mainly by slime worms and *Chironomus* larvæ in the sludge; and its chlorophyll-bearing plants linger only along the edges in shallow water. With the advent of cooler weather and higher river levels, most of these marked symptoms disappear, and a few fishes may even make their

way into the stream, particularly along the south side in the vicinity of the mouths of creeks. In spring and in fall, bubbling from the bottom ceases, the odor of the water is no longer repellent, a few invertebrate animals reappear, and the oxygen ratios rise to a considerable fraction of those normal to the Kankakee. The extent of this seasonal oscillation depends, of course, upon the rainfall and temperature; and the opposite extreme is reached in winter, when midstream oxygen ratios may be fully as high as those of the summer time for Chillicothe and Peoria.

The Marseilles Dam.—The waters of the stream change but little between Morris and the Marseilles dam, the oxygen content being sometimes a little higher at one point and sometimes at the other. The mean of eight sets of determinations in six different months was 4.5 parts per million for Morris and 4.3 at Marseilles above the dam. The water is usually somewhat freer of sewage organisms at Marseilles than at Morris. This is evidently owing in part to sedimentation of suspended particles, especially the larger ones, in the slackwater above the dam, where the current, even at flood stages, was only about half a mile an hour. Both plants and animals are a little more varied and abundant at Marseilles in sheltered pockets along the banks; and a larger variety of fishes was obtained at the edge of the river close to the mouths of creeks.

The interesting feature of the Marseilles situation is the effect produced by the fall over the dam* at low water. In samples taken far enough below the fall to give the air caught in the water ample opportunity to escape, we found the ratios of dissolved oxygen in July and August, 1911, more than three times as great as those above, from one and a half to two times as great in August and September, 1912, when the water was cooler and the river higher than in the midsummer of the previous year, and 13 to 14 per cent. greater under winter conditions in February and March. This difference in oxygen doubtless had its effect upon the abundance of fishes, although these might well be expected to be more numerous below the dam than above, even if the oxygen supply were the same. The fish population was, however, small and scanty, if we may judge by our collections, consisting mainly of carp, bullheads, and the ever-present shiner in the main stream, with a considerable variety of species in shallow water near the mouths of tributaries. Black bass were reported to us to come up to the dam only in the highest water.

Ottawa and Starved Rock.—At Ottawa and Starved Rock a con-

*This dam is about 710 feet in length, and its height is about ten feet above the rock-bed of the river. (E. H. Heilbron, in letter.)

siderable progressive improvement of river conditions was manifest, due to sedimentation, to self-purification, and to dilution with cleaner tributary waters. Oxygenation increased between Marseilles below the dam and Starved Rock by 36 per cent. in August and by 14 per cent. in September, but in February it was the same at these two stations. Other evidences of sewage contamination were similarly diminished—the color of the water, the number of foul-water organisms either suspended in the water or growing at the edges, the scarcity and small variety of fishes resorting to the middle of the stream—until at Starved Rock we got our first somewhat representative collections of distinctly main-stream fishes—gizzard-shad, redhorse, carp, bullheads, and black bass. Although the slack-water sludges were scarcely changed in character from those farther up the stream, living mussels began to appear in this section in small variety, but mainly in the cleaner water of the Fox; decapod and isopod crustaceans (crawfishes and *Asellus*) came in here in some numbers; and sponges and *Bryozoa* put in an appearance in especially favorable spots. The contaminational blue-green algæ, common along shore above, practically vanished; and the chlorophyll-greens changed from *Stigeoclonium tenue* as the dominant form to species of *Cladophora,* significant of cleaner water. The degrees of this improvement varied, of course, as usual, with the temperature and the stage of water.

Spring Valley.—It was at Spring Valley, fifty-seven miles below the mouth of the Des Plaines, that, in summer time, the last visible symptoms of water pollution were to be seen. The water here had not yet recovered its normal slightly greenish tint, but was still grayish with suspended specks of septic and pollutional plankton; and it still smelled slightly of sewage, in part no doubt because of local contamination from Peru and La Salle, a few miles above. It was here that the little amphipod crustacean, *Hyalella knickerbockeri,* made its first appearance below the Kankakee, and here that the first specimens of the river shrimp, *Palæmonetes exilipes,* were collected. A considerable variety of aquatic insect larvæ, of living mussels, and of gastropod mollusks, and a much smaller proportion of dead shells, testified further to an improved environment. This was also the first place on the river in which commercial fishing operations were being carried on at any time.

These biological tests were more favorable to the Spring Valley situation than the chemical; but they are, on the whole, more reliable, if they are used with intelligence and discretion, because they show the accumulated general consequences of local conditions, favorable and unfavorable, while the chemical determination applies only

to the moment and to the place of the collection of the sample tested.

Hennepin to Henry.—At Hennepin it may be fairly said that virtually normal conditions were found, except for the state of the bottom in winter time; although it must be confessed that our chemical data, especially those for the midsummer low-water of 1911, were hardly consistent with this statement. Only 22 to 28 per cent. of oxygen saturation, with carbon dioxide running up to 7.5 parts per million, are ratios very far from those normal to an uncontaminated stream; and the highest oxygen ratio found here at any time was 82 per cent. of saturation in November. Nevertheless, the greenish tint of the water caused by the chlorophyll-bearing plankton, the virtually complete disappearance of septic and pollutional organisms, the inoffensive odor of the bottom sediments, except in winter, the great predominance of living over dead specimens of the twenty-two species of mussels taken here, and the appearance, even in hot summer weather, of suckers, crappie, warmouth, and blue-gill sunfish in the products of our seines, showed that biological tests must be added to those of chemical analysis if we are to have a fair picture of the stages of recovery in a heavily polluted stream.

Henry to Chillicothe.—In this, the last section of the upper Illinois systematically studied by us in 1911 and 1912, the process of renovation is simply carried a little farther on than in the Henry-to-Hennepin section just above. It is only in the winter time that the effects of pollution are manifest here to the senses, in the more or less rank and repellent odor of the sediments at the Henry dam, and even of those from the bottom of the open channel at Chillicothe; and it is perhaps in part to this condition that we must attribute the reported great reduction in numbers of large catfish and of buffalo from this part of the stream.

There are, indeed, many species of fishes, most of them characteristic bottom-feeders, which were formerly common in the upper part of the Illinois River, taken in quantity there by fishermen several years ago, but which are now either wanting, rare, or greatly reduced in numbers. The large catfishes, the red-horse, the buffalo, and the sheepshead are examples; and even the bullheads are said to be less common at Henry and Depue than in former years. On the other hand, the sunfishes, crappies, and bass are likewise reported to be decreasing of recent years, at least at Henry and Depue. Indeed, the reported recent reduction in numbers of the more abundant food fishes clearly becomes more pronounced as we go up stream from Chillicothe to Depue, although fishing operations are less active northward—a fact which points to unfavorable river conditions as a probable cause of this diminished yield.

General Summary of Chemical Features

The foregoing general discussion of the assemblage of conditions, chemical and biological, found at each of our observing stations in succession for the entire period of our observations, may well be supplemented by a separate recapitulation of the more important chemical features of the river situation made to include oxygen determinations from the middle and lower Illinois as well as from the upper part of the stream, and from the Mississippi near its mouth—a form of discussion which will bring out a few conclusions not easily arrived at in any other way.

July and August, 1911.—The lowest ratios of dissolved oxygen in the upper Illinois were found in July and August, 1911. When determinations at the mouth of the Kankakee varied but little from 10 parts per million, those from the midstream at Morris, nine miles below, ranged from .24 to 1.78; at Marseilles, above the dam, seven miles farther down, they averaged .67, and below the dam 2.18; and at Starved Rock, 3.18. At Chillicothe the ratios varied on different days from 2.10 to 4.21 parts per millon, with an average of 3.47. Single determinations at this lowest of our river stations yielded as little as 19.5 per cent. of saturation, and the average of all our midsummer determinations here for 1911 was but 40.8. As the Kankakee River average at this time was 112.2, it appears that during the upper ninety-three miles of its course the Illinois did not regain much more than a third of the oxygen lost to the Chicago sewage.

Heavy general rains from the 10th to the 12th in the upper Illinois basin disturbed river conditions materially, bringing the Kankakee up about six inches at its mouth and the Illinois eight inches at Marseilles and raising the levels below. Our trips for collections and chemical analyses were made on three rounds from Dresden Heights to Chillicothe, the first ending a week before these rains began, the second beginning at Dresden Heights on the date of the principal rainfall, and the third following ten days after the rains were over. Our oxygen tests are comparable for these trips at the following five points: Dresden Heights, Morris, Marseilles above the dam, Marseilles below the dam, and Chillicothe. At all these places except Morris the oxygen ratios were considerably lower after the rain than before, the decline being greatest (50 per cent.) at Chillicothe, nearly a week after the rains. Averaging the readings for these five points on the three successive trips, we got the same mean oxygen ratio, of 3.64, for both the first and the last trips, and 3.17 for the intermediate one, indicating a decline of 13 per cent. in

the oxygen of the river water after the rains, followed presently by a return to the original mean.

This effect is graphically illustrated by Figure 2, Plate LXXX, where two of the lines, representing the first and last trips, run closely parallel from Marseilles onward, while the line for the intermediate trip diverges from the others to an increasing degree from Marseilles to Chillicothe. These interesting facts may be taken as suggestive of a general fouling of the water of the stream by heavy midsummer rains coming after a long period of heat and of dry weather. A general flooding and scouring of the surface of the country, washing off of the streets of towns, and flushing out of sewers, caused by heavy rains, may be supposed to bring into the river water containing larger ratios of organic matter than the stream itself; and to these we must probably add the stirring up and carrying off of the largely organic bottom sediments of the main river.

The carbon dioxide ratios in July and August, 1911, varied from none to 2.1 for the Kankakee River, and rose as high as 12.8 at the mouth of the Des Plaines and 11.1 at Morris and Marseilles. The Illinois River ratios were lowest at Chillicothe, where, however, the mean for the three sets of determinations, August 3, 17, and 29, was 6.3 parts per million. This is to be compared with a mean of .8 for the Kankakee River for the same period.

September, 1911.—During the second week in September, 1911, when the oxygen in the midstream at Morris averaged .59 parts per million and that of the Illinois just above the outlet of Depue Lake, near Hennepin, stood at 2.65, waters from the middle of Depue Lake itself contained 11.78 parts per million, equivalent to 42 per cent. above the saturation point at the prevailing temperature of the lake water. Even the Illinois and Michigan Canal at Morris, considerably contaminated with Chicago sewage as it is, contained at this time 6.8 parts per million of oxygen when the waters of the Illinois River gave 2.03 for the south or Kankakee side, and .88 for the north bank, or Des Plaines water.

November, 1911.—The effect of a higher temperature and higher water levels was clearly shown in November, 1911, by the much higher oxygen ratio at all points on the upper Illinois. The river, having lately fallen about three feet, was still, at this time, some two feet higher than in the preceding July and August, and the temperature of the water had declined from 72.5° F., the mean of our midsummer readings, to 46°, the mean for November 1 to 8 (8:30—9 a. m.). The following is a table of parts per million of oxygen at the points where comparable tests were made.

	Mid-summer 1911	Nov. 1-8 1911
Des Plaines River	1.21	4.7
Morris	1.15	4.6
Marseilles	.67	9.9
Hennepin	2.85	9.8
Chillicothe	3.47	9.8

This is an average increase of 5.7 parts per million, or of 300 per cent., of November over midsummer ratios for this part of the Illinois River.

February and March, 1912.—A trip was made for chemical determinations February 1 to 8, 1912, from Lockport to Chillicothe, and another, March 18 to 28, from Lockport to the mouth of the Illinois at Grafton. The water temperatures averaged 34° F. on the first trip, and 35° on the second, the upper river being quite frozen over much of the time.

The oxygen determinations of these trips differ widely from those of the preceding midsummer in the much higher ratios found in the winter and in the fact that the lowest point for oxygen was very much farther down the stream. In all our midsummer trips this lowest point was reached at the Marseilles dam, but in February there was less oxygen at Chillicothe than at Marseilles, and in March, when the whole length of the river was traversed, the oxygen ratios declined down stream from Marseilles to Havana, rising then gradually to the mouth of the Illinois. At Morris the ratio of oxygen was more than six times as great in February as in midsummer; above the dam at Marseilles it was more than eight times as great; below the dam more than three times; and at Chillicothe it was 30 per cent. greater. The March ratios from Morris down were much higher still, reaching a maximum of 10 parts per million below the Marseilles dam, falling thence rapidly to Peoria (6.8), dropping a trifle only at Peoria below the outlets of the sewer system (6.5), declining slightly to Havana (6.2), and then rising steadily to the mouth of the Illinois (9.4), the water of the Mississippi standing at the same time at 10.5. In the entire distance from Lockport to Grafton the percentage of oxygen saturation on this March trip did not fall below 44 (Peru), nor rise above 75 (south shore at Morris).

July, 1912.—A single trip was made July 11 to 15, 1912, in company with the chemists of the Sanitary District of Chicago, commencing, unfortunately for our purposes, at Peru, and giving us no

data, consequently, for the interesting section of the river above Marseilles. As this trip extended to the mouth of the Illinois, it can be used from Chillicothe downward as an extension of the midsummer trips of the preceding year, which stopped at that point, to give us an idea of midsummer conditions for the whole stream. It is mainly interesting as showing an irregular but gradual rise in oxygen ratios from Chillicothe to the Mississippi, from 2 parts per million at the former place to 4.7 at Twelve-mile island, thirteen miles above the junction of the Illinois with the Mississippi. A cross-section of the latter river at Grafton, below the junction, gave 4.85 parts per million on the Illinois shore below the mouth of the Illinois River, of 7.15 at the middle of the Mississippi, and of 7.65 on the Missouri side beyond the reach of Illinois River water. Otherwise stated, while the oxygen of the water of the Illinois near its mouth lacked in July 39.5 per cent. of saturation, that of the undiluted Mississippi lacked only 1.5 per cent. The residual effect of the contamination of the former stream was thus a final loss of 38 per cent. of its oxygen.

August to October, 1912.—Our chemist made in August, September, and October, 1912, only short visits to the river to determine the oxygen ratios where biological collections were in progress, and his data are consequently in fragmentary series only. Four tests made August 21 and 22 at Marseilles, Ottawa, and Starved Rock are of interest for comparison with those made at Marseilles and Starved Rock August 24 to 26, 1911, as shown by the following table.

	1911	1912
Marseilles (above dam)	.44	1.90
" (below dam)	2.26	2.90
Ottawa		3.65
Starved Rock	3.43	4.05

The mean of the water temperatures for the 1911 period was 70.5° F., and that for August, 1912, was 6° lower; and the river levels at Morris stood some six feet higher in August, 1912, than in August, 1911. These differences of conditions are fairly reflected in the virtual doubling up of the oxygen ratios in 1912 at the contrasted points.

November, 1912.—For November, 1912, we have two trips, a fortnight apart, made the entire distance from Lockport to the

Mississippi River. The data thus obtained resemble each other closely in the general trend of the series of determinations, from a very low ratio at Lockport, with a considerable and rather steady rise to Peoria (10.5 parts per million), and nearly uniform ratios thence to the mouth of the Illinois. The later series, of November 12 to 19, runs on an average considerably higher than the earlier, November 1 to 7, but notwithstanding the saturation percentage of 87 at the mouth of the river (10.7 parts per million) it presents the strongest contrast with the Mississippi River, the midstream waters of which contained at this time 14.2 parts per million, amounting to 114 per cent. of saturation. There was no place on the Illinois on either of these trips where the oxygen ratios were less than 4.6 parts per million.

THE EFFECT OF A DAM ON DISSOLVED GASES

The fall over the Marseilles dam in the hot weather and low-water period of July and August, 1911, had the effect to increase the dissolved oxygen more than four and a half times, raising it from an average of .64 parts per million to 2.94 parts. On the other hand, with the cold weather, high oxygen ratios, and higher water levels of February and March, 1912, and the consequent reduced fall of a larger volume of water at Marseilles, the oxygen increase was only 18 per cent.—from 7.35 parts per million above the dam to 8.65 parts below; and in August and September, 1912, the weather being still cooler and the water lower than in the midsummer of the previous year, the increase was only 77 per cent.—from 2.05 parts per million above the dam to 3.62 parts below. It should be noted, however, that this beneficial effect is greatest when it is most needed—when the pollution is most concentrated and decomposition processes are most active. In the absence of a dam at this point, the recovery of oxygen used up in decomposition would be greatly retarded in midsummer, and heavily polluted water would be carried much farther down the stream.

A reverse but much less pronounced effect is produced at the dam upon the carbon dioxide content of the waters of the stream. This was diminished, in the summer of 1911, from 8.2 parts per million above to 6.48 parts below the dam—a reduction of 21 per cent. The ratio of loss of carbon dioxide was thus only a seventeenth part of the ratio of gain in oxygen. A similar statement may be made concerning losses and gains of these gases for the upper Illinois River as a whole. Taking the means of the oxygen ratios at each point for the period from July 28 to August 29, 1911, we find them rising

from 1.35 at Morris to 3.82 at Chillicothe—an increase of 183 per cent.; while the carbon dioxide drops from 7.7 to 6.1, a loss of 22 per cent.—the greater part of both changes occurring, in fact, at the Marseilles dam. It will thus be seen that in judging of the biological effects of pollution and self-purification of the stream, we must take note of the fact that a given increase or decrease in carbon dioxide is accompanied by a loss or gain in oxygen from eight to seventeen times as great.

SEASONAL PHASES OF CHEMICAL CONDITION

The combination of our tables and our graphs by seasons, and a comparison of these sets of seasonal data one with another, brings out clearly three phases in river condition which may be called the midsummer, fall, and winter phases, and implies also a fourth or spring phase, for which we have at present no data. The midsummer and the winter phases represent, of course, the extremes between which the fall and spring conditions come as intermediate or transition stages. The midsummer phase, with its high temperatures and low stage of water, is characterized by a concentrated pollution and an early and rapid decomposition and deoxygenating process, with lowest oxygen readings at Morris and above the dam at Marseilles, followed by a sudden increase of oxygen below the dam and a gradual rise in ratios thence down the stream to its mouth. The winter phase contrasts with this by a delay of decomposition such that the oxygen ratio is highest at Marseilles, declines slowly to the middle of the river's course, (about at Havana,) and then rises gradually to its mouth. In the autumnal transition phase the oxygen ratio is at its lowest point in the Dresden Heights-Marseilles section, although much higher there than in midsummer, rises thence slowly to Peoria, and continues on an approximately level line to the mouth of the Illinois. In the spring phase a transition in the opposite direction probably gives somewhat similar results, modified, however, by the spring floods, which are usually much larger than those resulting from the fall rains, and by differences in the antecedent seasonal conditions from which this spring transition makes its start.

These periodical changes in the distribution of oxygen and carbon dioxide within the stream are, of course, consequent upon seasonal differences in temperature and stage of water, influenced considerably by the upper dam, at Marseilles; and the above descriptions may perhaps need modification to make them applicable to notably unusual years.

ADDITIONAL DATA UPON THE RIVER SLUDGES

Since this manuscript was prepared we have received from the chemists of the Water Survey a report on the following series of nine sludge samples collected in March, 1913, with a view to determining the winter condition of the river sediments throughout the length of the stream. It will be seen that they agree in the main with the short series on page 00 to the effect that a marked change occurs between Marseilles and Henry, and that they show a gradual improvement in respect to organic contents in the samples obtained below Peoria.

ANALYSIS OF SLUDGES FROM THE ILLINOIS RIVER

Date collected 1913	Source, water temperature, and odor	Specific gravity	Moisture	Per cent. in terms of dry matter			
				Nitrogen	Loss on ignition	Fixed matter	Ether soluble
March 18	Drainage Canal, Lockport; 37° F; fecal.	1.20	71.2	.55	22.2	77.8	2.67
17	Illinois River, Morris; 36° F; fecal.....	1.35	53.6	.51	16.2	83.8	1.12
19	Illinois River, Marseilles; 40° F; fecal	1.24	44.3	.67*	10.	90.	1.07
20	Illinois River, Henry; 41° F; disagreeable.....	1.28	63.	.39	12.1	87.9	.40
26	Illinois River, Chillicothe; 39° F; disagreeable...	1.38	48.3	.39	11.6	88.4	.36
April 5†	Illinois River, Peoria Narrows..	1.69	32.1	.14	6.8	93.2	.28
March 25	Illinois River, Copperas Creek; 43° F; earthy ...	1.58	40.2	.15	4.8	95.2	.11
24	Illinois River, La Grange; 43° F; earthy.....	1.57	37.4	.20	5.3	94.8	.11
22	Illinois River, Pearl; 41° F; earthy..... ..	1.77	29.8	.12	3.2	96.8	.18

*Large numbers of sewage worms in this sample account for the high nitrogen content.
†Date received at laboratory.

TABLE OF DISSOLVED OXYGEN AND CARBON DIOXIDE, ILLINOIS RIVER AND RELATED WATERS, 1911 AND 1912

Water	Location	Date	Hour	Depth of sample	Water Temp. C.	Water Temp. F.	Dissolved oxygen, p.p.m.	Dis. oxygen % sat'n.	Carbon dioxide, p.p.m.	Remarks
		1911								
Lake Michigan	Chicago	July 18	12 m.	3 ft	20.3	68.5	7.91	87.4		39th St. pier
" "	"	"	3:30 p.m.	3 ft	21.4	70.5	9.25	103.6		39th St. pier
Illinois River	Morris	July 22	10 a. m.	5 ft	24.8	76.4	.30	3.4		Midstream
" "	"	"	1:30 p.m.	5 ft	25.	77.	.26	3.1		"
" "	"	"	4 p.m.	5 ft	24.5	77.	.17	2.0		Midstream
" "	"	"	10 a.m.	3 ft	24.5	77.	.04	0.5		40 ft. from south bank
" "	"	"	1:30 p.m.	3 ft	25.	77.	.28	3.3		" " "
" "	"	"	4 p.m.	3 ft	24.5	77.	.31	3.5		" " "
Kankakee River	Dresden Heights	July 24	2 p.m.	18 in	20.0	68.	9.91	107.9		Midstream
" "	" "	" 26	2 p m.	12 in	22.	72.	11.21	126.8	2.1	12 ft. from east bank
Des Plaines River	" "	" 27	10 a.m.	5 in	20.	68.	1.25	13.6	12.8	At the dam
" "	" "	" 27	1:30 p.m.	5 in	20.	68.	1.17	12.7	12.8	At the dam
Illinois River	Morris	" 28	7:30 a.m.	5 in	20.	68.	1.24	13.5	8.2	Midstream
" "	"	" 28	1:30 p.m.	5 in	20.	68.	.91	9.9	14.1	Midstream
" "	Marseilles	" 30	9:30 a.m.	9 ft	21.	70.	.80	8.9	5.9	Midstream, above dam
" "	"	" 30	9:30 a.m.	18 in	21.	70.	.86	9.5	5.9	" " "
" "	"	" 31	10 a.m.	18 in	21.6	71.2	2.64	29.9	5.8	¾ mile below dam; 8 ft. from shore.
" "	Peru	Aug. 2	8:30 a.m.	18 in	21.9	71.8	3.20	36.	6.9	Above canal
" "	"	" 2	9 a.m.	18 in	21.9	71.8	3.17	35.8	6.6	At bridge, south side
" "	"	" 2	1:30 p.m.	18 in	22.	72.	3.51	39.6		" "
" "	Chillicothe	" 3	11 a.m.	10.5 ft	24.4	76.8	4.29	50.4	5.9	¼ mile above landing
" "	"	" 3	11 a.m.	18 in	24.4	76.8	4.59	53.9		" " "
" "	"	Aug. 4	9:30 a.m.	10.5 ft	24.4	76.8	3.71	43.6	6.	¼ mile above landing
" "	"	" 4	9:30 a.m.	18 in	24.5	77.	4.24	50.3	5.6	" " "
Kankakee River	Dresden Heights	Aug. 10	10:30 a.m.	18 in	26.	79.	8.67	105.9	.7	⅛ mile above mouth, 30 ft. from east bank
" "	" "	" 10	2:30 p.m.	18 in	28.	83.	10.54	133.1		Same location as above
Illinois River	Morris	" 11	8 a.m.	18 in	22.	72.	1.85	20.9	8.5	Midstream

TABLE OF DISSOLVED OXYGEN AND CARBON DIOXIDE, ILLINOIS RIVER AND RELATED WATERS, 1911 AND 1912 — *Continued*

Water	Location	Date	Hour	Depth of sample	Water Temp. C.	Water Temp. F.	Dissolved oxygen, p.p.m.	Dis. oxygen % sat'n.	Carbon dioxide, p.p.m.	Remarks
Illinois River ..	Morris.	Aug. 11	1:30 p.m.	18 in	22.	72.	1.72	19.5	6.9	Midstream
" "	Marseilles.	" 12	8:30 a.m.	18 in	22.	72.	.98	11.	11.2	¼ mile above dam
" "	"	" 14	8:15 a.m.	18 in	22.5	73.	.48	5.5	11.1	¼ mile above dam after heavy rain; river up 8 in.
" "	"	" 14	9:15 a.m.	4 in	22.5	73.	1.65	18.9	8.7	¾ mile below dam; 3 ft. from bank
" "	Starved Rock....	" 15	9:45 a.m.	12 in	25.	77.	2.58	30.9	7.4	Near south side
" "	"	" 15	1 p.m.	12 in	25.	77.	2.62	31.4		" " "
" "	"	" 15	10:45 a.m.	12 in	25.	77.	3.18	38.		Near north side
" " ..	" ...	" 15	1:30 p.m.	16 in	25.	77.	3.34	40.	7.3	" " "
" "	Hennepin.....	" 16	9:30 a.m.	18 in	25.5	78.	2.22	26.8	7.5	Midstream
" " ..	"	" 16	1 p.m.	18 in	26.5	80.	2.27	28.	7.5	"
" "	Chillicothe.	" 17	9 a.m.	18 in	26.	79.	2.33	28.4	6.7	"
" "	"	" 17	1 p.m.	18 in	26.	79.	2.37	28.9	6.9	"
Kankakee River.	Dresden Heights.	Aug. 21	10:30 a.m.	18 in	23.	73.	8.47	97.6		30 ft. from east bank
" "	"	" 21	2 p.m.	18 in	24.2	76.4	10.15	119.3		" " "
Illinois River....	Morris.	" 22	9:30 a.m.	18 in	22.5	73.	1.37	15.7	6.7	Midstream
" "	"	" 23	8 a.m.	18 in	22.6	73.2	1.47	17.	6.4	"
" "	Marseilles.	" 24	8:15 a.m.	18 in	21.7	71.4	.55	6.2	8.0	" above dam
" "	"	" 25	12:15 p.m.	18 in	21.	70.	.78	8.6	8.6	" " "
" "	"	" 24	9 a.m.	9 in	21.5	71.	1.73	19.4	5.9	¾ mi. below dam; 6 ft. from bank
" "	"	" 25	1 p.m.	9 in	21.2	70.4	2.80	31.	6.2	Below dam; 6 ft. from bank
" "	Starved Rock....	" 26	9:15 a.m.	9 in	21.	70.	3.07	34.	5.8	South side
" "	" ..	" 26	10:30 a.m.	12 in	21.5	71.	3.72	41.7	5.4	North side
" "	"	" 26	12:30 p.m.	12 in	22.	72.	3.87	43.8	5.5	North side
" "	Hennepin.....	" 28	9:30 a.m.	18 in	22.	72.	3.28	37.1	6.4	Midstream
" "	"	" 28	2 p.m.	18 in	23.2	74.4	3.62	41.7	6.0	"

TABLE OF DISSOLVED OXYGEN AND CARBON DIOXIDE, ILLINOIS RIVER AND RELATED WATERS, 1911 AND 1912 — *Continued*

Water	Location	Date	Hour	Depth of sample	Water Temp. C.	Water Temp. F.	Dissolved oxygen, p.p.m.	Dis. oxygen % sat'n.	Carbon dioxide, p.p.m.	Remarks
Illinois River	Hennepin	Aug. 28	9:45 a.m.	18 in	22.	72.	3.50	39.6	6.4	50 ft. from east bank
" "	"	" 28	2:15 p.m.	18 in	23.5	75.	3.50	40.7	6.8	" " " "
" "	Chillicothe	" 29	9:30 a.m.	18 in	22.5	73.	3.95	45.1	6.3	Midstream
" "	"	" 29	3 p.m.	18 in	22.8	73.6	4.28	49.4	6.1	"
" "	"	" 29	12 m.	18 in			4.60		4.9	East side of island
Illinois River	Morris	Aug. 31	8:30 a.m.	18 in	20.	68.	1.05	11.4		Midstream
" "	"	" 31	1:30 p.m.	18 in	22.	72.	1.18	13.3	7.4	"
" "	"	" 31	8:30 a.m.	1 in	20.8	69.6	3.5	38.9	7.2	4 in. deep near shore; over Stigeoclonium
" "	"	" 31	1:30 p.m.	1 in	22.3	72.6	6.1	69.	4.2	4 in. deep near shore; over Stigeoclonium
" "	Marseilles	Sept. 1	8:30 a.m.	18 in	21.	70.	.58	6.4	7.4	Above dam
" "	"	" 1	9:15 a.m.	6 in	21.2	70.4	5.90	65.4	5.8	⅛ mile below dam
" "	Ottawa	" 2	11:30 a.m.	6 in	23.	73.	4.75	54.8		Near south shore, above Fox; water 2 feet deep
" "	"	" 2	1:45 p.m.	6 in	23.7	75.4	5.50	64.6	4.6	Near south shore, above Fox; water 2 feet deep
" "	"	" 2	2:45 p.m.	6 in	23.8	75.6	5.82	68.4	4.2	Near south shore, above Fox; water 2 feet deep
" "	"	" 2	3:40 p.m.	6 in	23.7	75.4	5.70	70.	4.35	Near south shore, above Fox; water 2 feet deep
" "	"	" 2	4:30 p.m.	6 in	23.7	75.4	5.42	63.7	4.7	Near south shore, above Fox; water 2 feet deep
" "	"	" 2	5:30 p.m.	6 in	23.7	75.4	4.87	56.9	5.5	Near south shore, above Fox; water 2 feet deep
" "	Morris	" 8	2 p.m.	18 in			.70			Midstream
" "	"	" 9	7:30 a.m.	18 in			.50			"
" "	"	" 9	1:30 p.m.	18 in			.68			"

TABLE OF DISSOLVED OXYGEN AND CARBON DIOXIDE, ILLINOIS RIVER AND RELATED WATERS, 1911 AND 1912 — *Continued*

Water	Location	Date	Hour	Depth of sample	Water Temp. C.	Water Temp. F.	Dissolved oxygen, p.p.m.	Dis. oxygen % sat'n.	Carbon dioxide, p.p.m.	Remarks
Illinois River ...	Depue	Sept. 11	11:15 a.m.	18 in	22.5	73.	2.65	30.3	7.16	Above outlet of lake
Depue Lake.....	"	" 11	2 p.m.	18 in	24.8	77.6	12.92	155.		Middle of lake
Illinois River	Morris.	Sept. 13	7:30 a.m.	18 in	20.8	69.6	2.03	21.4		Near south bank
" "	"	" 13	11 a.m.	18 in	21.2	70.4	.88	9.7		Near north bank
Ill. Mich. Canal..	"	" 12	5 p.m.	18 in			6.80			
Drainage Canal..	Lockport.....	Nov. 1	10 a.m.	2 ft		50.	2.5	22.1		
							2.5	22.1		East bank of canal
Des Plaines R ...	"	" 2	10 a.m.	10 in		51.	5.2	46.		Near east bank; water 1 foot deep
							4.7	42.		
Illinois River ..	Morris.	" 3	9 a.m.	2 ft		41.	3.6	28.1		
							3.7	28.9		Midstream
" "	"	" 3	2 p.m.				5.5			
							5.6			Probably farther from north bank
" "	"	" 3	9 a.m.	2 ft			10.8	84.4		Near north bank
" " ...	Marseilles. ..	" 4	9 a.m.	2 ft		43.	10.	80.6		Above dam
" " . .	Hennepin	" 7	8:30 a.m.	2 ft		46.	9.8	82.3		
							9.7	81.5		Midstream
" " .	Chillicothe.	" 8	10 a.m.	2 ft		45.	10.2	84.4		
							10.1	83.6		Midstream
		1912								
Illinois River	Morris.....	Feb. 16	10 a.m.		2.	35.6	7.2	51.9		
			3 p.m.		1.	33.8	7.6	53.2		
							7.5	52.5		South shore
" "	"	" 16	10 a.m.	2 ft	2.	35.6	7.2	51.9		
			3 p.m.		1.	33.8	6.9	48.3		
							6.8	47.6		Center of channel

TABLE OF DISSOLVED OXYGEN AND CARBON DIOXIDE, ILLINOIS RIVER AND RELATED WATERS, 1911 AND 1912 — *Continued*

Water	Location	Date	Hour	Depth of sample	Water Temp. C.	Water Temp. F.	Dissolved oxygen, p.p.m.	Dis. oxygen % sat'n	Remarks
Illinois River	Morris	Feb. 16	10 a.m.	8 ft	2.	35.6	7.2	51.9	
			3 p.m.		1.	33.8	6.3	44.1	Center of channel
" "	"	" 16	10 a.m.		2.	35.6	6.6	47.5	
			3 p.m.		1.	33.8	6.3	44.1	North shore
Des Plaines R...	Lockport.....	" 17			1.5	34.7	8.6	61.2	
							8.9	63.3	
Drainage Canal..	"				1.	33.8	9.4	65.8	
							9.2	64.4	
Kankakee River.		" 19			.5	32.9	9.	62.	
							9.1	62.7	
Illinois River	Marseilles	" 20			3.	37.4	6.3	46.7	South shore, above dam
" " ...	"	" 20			3.	37.4	5.9	43.7	Center of channel
" " ...	"	" 22			.5	32.9	7.1	48.3	North shore
" " ...	"	" 22			.5	32.9	7.3	49.6	Below dam
" " ..	Starved Rock...	" 23			.5	32.9	7.3	50.4	
" "	Chillicothe.	" 24			2.	35.6	5.	36.	
Des Plaines R. ..	Lockport	Mar. 18			2.5	36.5	6.5	47.5	
Chicago Drainage Canal.....	"	" 18			3.	37.4	6.3	46.7	
Illinois River....	Morris	" 19			1.5	34.7	10.4	73.8	South shore
" " ...	"	" 19			1.5	34.7	9.2	65.4	North shore
" " ...	Marseilles.	" 21			0.0	32.	8.8	59.8	Above dam

TABLE OF DISSOLVED OXYGEN AND CARBON DIOXIDE, ILLINOIS RIVER AND RELATED WATERS, 1911 AND 1912 — *Continued*

Water	Location	Date	Hour	Depth of sample	Water Temp. C.	Water Temp. F.	Dissolved oxygen, p.p.m.	Dis. oxygen % sat'n.	Remarks
Illinois River...	Marseilles	Mar. 21			0.0	32.	10.	68.	Below dam
" " ...	Chillicothe.. . .	" 22			0.0	32.	7.2	49.	
" "	Peoria	" 23			0.0	32.	6.8	46.3	Above sewer outlet
" " ...	"	" 23			0.0	32.	6.5	44.2	Below sewer outlet
" "	Havana	" 25			2.	35.6	6 2	44.6	
" "	Beardstown.....	" 26			1.5	34.7	7.7	54.7	
" "	Pearl	" 27			2.	35.6	9.3	67.	
" "	Grafton.	" 28			3.	37.4	9.4	69.7	
Mississippi R ...	"	" 28			3.	37.4	10.5	77.8	
Ill.-Miss. Canal..		July 11	8 a.m.		25.	77.	4.3	51.2	At junction with Illinois River
Illinois River	Peru.....	" 11			25.	77.	2.7	32.2	
" "	Spring Valley ...	" 11	9 a.m.		25.	77.	2.		
							1.9	23.3	
" "	Marquette.	" 11	9:30 a.m.		25.	77.	1.4		
							1.6	17.9	
					25.	77.	1.4		
" " ...							1.5	17.3	Opposite Ill.-Miss. Canal
Ill.-Miss. Canal . L.L.					28.	83.	5.2	65.7	
Illinois River ..	Hennepin	July 11	10:45 a.m.		25.	77.	1.8	21.5	
" "	Twin Sister Islands	" 11	11:15 a.m.		26.	79.	2.3		
							2.2	27.4	
Mud Lake.		" 11			26.	79.	7.70	93.8	1000 ft. from Ill. River
Illinois River ...		" 11			26.	79.	7.80	94.8	Mouth of Mud Lake
" "		" 11			26.	79.	2.60	31.6	½ mile below Mud Lake

TABLE OF DISSOLVED OXYGEN AND CARBON DIOXIDE, ILLINOIS RIVER AND RELATED WATERS, 1911 AND 1912 — *Continued*

Water	Location	Date	Hour	Depth of sample	Water Temp. C.	Water Temp. F.	Dissolved oxygen, p.p.m.	Dis. oxygen % sat'n.	Remarks
Illinois River	Henry	July 11	12:30 p.m.		26.	79.	2.1		
							2.5	28.	Above dam
" "	"	" 11			26.	79.	2.4	29.2	Below dam
" "	Lacon.	" 11	2 p m.		28.	83.	2.1		
							2.3	27.8	
" "		" 11	2:30 p.m.		28.	83.	2 7	34.1	Opposite Babb's Slough
" " ..	Chillicothe.....	" 11			28.	83.	2.5	31.6	East bank; cross section
" " ...	"	" 11			28.	83.	2.7		
							3.	36.	Middle, cross section
" " ...	"	" 11			28.	83.	2.8	35.4	West bank; cross section
" " ...	"	" 12	9:15 a.m.		25.	77.	2.		
							2.1	23.9	
Illinois River....		July 12			25.	77.	1.9	22.7	Opposite entrance to Peoria Lake
" "		" 12	10 a.m.		25.	77.	4.5	53.9	East bank, below Partridge Island
" "		" 12			25.	77.	2.		
							2.1	23.9	Middle, below Partridge Island
" " ...		" 12	10:15 a.m.		25.	77.	1.7	20.3	West bank, below Partridge Island
" " ...		" 12			25.	77.	3.2	38.2	Opposite Spring Bay
" " ...		" 12			25.	77.	5.3		
							5.4	62.	West bank, below Horse Haw Slough
" " ...		" 12			25.	77.	3.7	44.2	Middle, below Horse Haw Slough

TABLE OF DISSOLVED OXYGEN AND CARBON DIOXIDE, ILLINOIS RIVER AND RELATED WATERS, 1911 AND 1912—*Continued.*

Water	Location	Date	Hour	Depth of sample	Water Temp. C.	Water Temp. F.	Dissolved oxygen, p.p.m.	Dis. oxygen % sat'n.	Remarks
Illinois River	Peoria Heights..	July 12	12 m.		25.	77.	4.3		
							4.5	52.5	
" "	Averyville.....	" 12			26.	79.	6.9		
							6.8	83.4	East bank; cross section
" " ...	"	" 12			26.	79.	5.3	64.5	Middle; cross section
" " ...	"	" 12			26.	79.	5.9	71.8	West bank; cross section
" " ...	Peoria	" 12	3 p.m.		26.	79.	7.2		
							7.0	86.4	West bank, foot of Liberty street
" "	"	" 12			27.	81.	8.1		
							7.8	98.6	Middle, foot of Liberty street
" "	Wesley.	" 12			27.	81.	7.		
							6.7	85.	
" "	Pekin	" 12			27.	81.	5.4	67.	Below highway bridge
" " ...	"	" 12			27.	81.	6.4	79.3	East bank; public landing
" "	"	" 12			27.	81.	6.6		
							6.5	81.2	Below all distilleries
" " ...	"	" 12			27.	81.	6.1	75.6	At point of dung discharge
" "		" 12			27.	81.	5.6	69.4	Between Pekin and Mackinaw River
" " ...		" 13	5 p.m.		27.	81.	5.2	64.4	Above Mackinaw River
" " ...		" 13			27.	81.	5.4	67.	Below Mackinaw River
" " ...		" 13	7:45 a.m.		26.	79.	5.3	64.5	Above Mackinaw River
" " ...	Kingston Mines..	" 13			26.	79.	4.1		
							4.6	52.3	Opposite the town
" " ...		" 13				79.	3.6		
					26.		3.3	42.	At 141-mile Point
" "	Copperas Creek..	" 13				79.	3.8		
					26.		4.	47.4	Above dam

Water	Location	Date	Hour	Depth of sample	Water Temp. C.	Water Temp. F.	Dissolved oxygen, p.p.m.	Dis. oxygen % sat'n.	Remarks
Illinois River....	Copperas Creek..	July 13			26.	79.	3.7	45.	Below the dam
" "	Liverpool	" 13	10:15 a.m.		27.	81.	3.6	44.6	
" "		" 13			29.	85.	4.6		
							4.9	61.1	Above Spoon River
Spoon River.....		" 13			28.	83.	5.7		
							5.6	71.3	At mouth
Illinois River...		" 13			27.	81.	3.7	45.9	Below Spoon River
" "	Havana.....	" 13	11:30 a.m.		27.	81.	3.6		
							3.7	45.2	Middle
" "	Grand Island	" 13		6 ft	29.	85.	3.3	42.5	Above
" " ...	" " ...	" 13		2 ft	29.	81.	3.4		
							3.6	45.	"
" "	" " ...	" 13			28.	83.	4.9		
							4.7	60.6	Below
" "	Sharp's Landing.	" 13			27.	81.	4.7		
							4.4	56.4	
" "		" 13			27.	81.	6.2		
							5.9	76.2	At Panther Slough
" "		" 13			27.	81.	6.2		
							6.3	77.4	Below Island
" "	Browning.....	" 13	4:30 p.m.		27.	81.	3.8	47.1	
" "		" 13	5 p.m.		27.	81.	3.7		
							3.6	45.2	Opposite Big Lake
" "	Beardstown.....	" 13	5:30 p.m.		29.	85.	3.7	47.6	West bank; cross section
" "	"	" 13			28.	83.	4.8	50.6	Middle; cross section
" "	"	" 13			28.	83.	5.3	67.	East bank; cross section
" "	"	" 14	8:10 a.m.		27.	81.	4.2	52.	One mile below

TABLE OF DISSOLVED OXYGEN AND CARBON DIOXIDE, ILLINOIS RIVER AND RELATED WATERS, 1911 AND 1912 — *Continued*

Water	Location	Date	Hour	Depth of sample	Water Temp. C.	Water Temp. F	Dissolved oxygen, p.p.m.	Dis. oxygen % sat'n	Carbon dioxide, p.p.m.	Remarks
Illinois River		July 14	8:45 a.m.		27.	81.	3.8	47.1		One mile below Crooked Creek
" "	LaGrange	" 14			28.	83.	3.8			
							3.7	47.4		Above dam
" "	"	" 14	9:45 a.m.		28.	83.	4.6			
							4.5	58.1		Below dam
" "	Meredosia.....	" 14	10:30 a.m.		28.	83.	4.6			
							4.4	56.8		
" "	Naples	" 14	11:15 a.m.		27.	81.	4.4	54.6		
" "	Valley City	" 14			27.	81.	4.7	58.3		
" "	Florence	" 14	12:30 p.m.		28.	83.	4.6			
							4.7	58.7		
" "	Bedford.	July 14	1:15 p.m.		29.	85.	4.6	59.2		
" "	Pearl	" 14			30.	86.	4.7			
							4.8	62.2		
" "	Kampsville	" 14	3:30 p.m.		30.	86.	4.3	56.4		Above dam
Illinois River....	"	" 15	8 a.m.		28.	83.	4.3	54.3		Above dam
" " . ..	"	" 15	8:30 a.m.		28.	83.	4.6	58.1		Below dam
					29.	85.	4.6			
							4.7	59.8		At head of Diamond Island
" " . ..	Hardin.	" 15	9:30 a.m.		29.	85.	4.7	60.5		
" "		' 15	10:15 a.m.		29.	85.	4.8			
							4.7	60.5		Above 12-mile Island
Mississippi R ..	Grafton	" 15	11:45 a.m.		29.	85.	4.8			
							4.9	62.4		East bank; cross section
" "	"	" 15			29.	85.	7.1			
							7.2	92.		Middle; cross section
" "	"	" 15	12 m.		29.	85.	7.6			
							7.7	98.5		West bank; cross section

TABLE OF DISSOLVED OXYGEN AND CARBON DIOXIDE, ILLINOIS RIVER AND RELATED WATERS, 1911 AND 1912 — *Continued*

Water	Location	Date	Hour	Depth of sample	Water Temp. C.	Water Temp. F.	Dissolved oxygen, p.p.m.	Dis. oxygen % sat'n	Remarks
Des Plaines R...	Lockport....	Aug. 6	1 p.m.	12 in	24.	76.	12.1	142.	Midstream; river very shallow
Drainage Canal..	Lockport.....	" 6	8 p.m.		22.5	73.	.5	5.	South side
Kankakee River.	Dresden Heights.	" 7	10 a.m.		21.5	71.	9.5	107.	Cloudy; shore sample
Des Plaines R...	" " .	" 7	11 a.m.		22.	72.	2.1	24.	" " "
Illinois River....	Morris.....	" 8	7 a.m.		20.5	69.	4.5	50.	South side; 30 ft. from bank
" "	"	" 8	8 a.m.		21.5	71.	2.1	23.	Midstream
" " ...	"	" 8	9 a.m.		22.	72.	.8	9.	North side; 30 ft. from bank
" "	Marseilles.....	" 8	2 p.m.		23.5	75.	1.9	22	Midstream; above dam
" "	"	" 8	12 m.		23.5	75.	4.4	51.	Below dam
" " ...	"	Aug. 21	1:30 p.m		23.	73.	1.9	21.9	
							1.8	20.8	Midstream; above dam
" " ...	Marseilles.....	" 21	2:30 p.m.		23.	73.	1.6	18.5	
							1.5	17.3	South side
" "	"	" 21			23.	73.	1.7	19.6	
							1.8	20.8	North side
" " ...	"	" 21	4:30 p.m.		23.	73.	2.9	33.5	Below dam
" " ..	Ottawa	" 22	3 p.m.		23.	73.	3.9	45.	
							4.	46.2	South side; above Fox River
" " ...	"	" 22			23.	73.	3.4	39.2	
							3.3	38.1	North side
" " ...	Starved Rock....	" 22	10 a.m.		23.	73.	4.5		
							4.4		North shore
" "	" "	" 22			23.	73.	3.7	42.7	
		" 22					3.6	41.5	South shore
Illinois River...	Hennepin.....	Sept. 6	11 a.m.		26.	79.	2.4	29.3	
							2.2	26.8	
							2.3	28.	Midstream

TABLE OF DISSOLVED OXYGEN AND CARBON DIOXIDE, ILLINOIS RIVER AND RELATED WATERS, 1911 AND 1912 — *Continued*

Water	Location	Date	Hour	Depth of sample	Water Temp. C.	Water Temp. F.	Dissolved oxygen, p.p.m.	Dis. oxygen % sat'n	Remarks
Illinois River...	Starved Rock....	Sept. 6	5 p.m.		26.	79.	2.4	29.3	
" "	" "	" 6	5:30 p.m.		26.	79.	2.5	30.5	South shore
							2.7	32.9	
							2.6	31.7	
" "	Chillicothe.	" 7	9 a.m.		26.5	80.	2.8	34.1	North shore
							2.7	33.3	
							2.6	32.1	
							2.7	33.3	Midstream
Des Plaines R..		" 26	10 a.m.		18.	65.	1.1	11.6	
							1.	10.4	Just above junction with Kankakee
Kankakee River.		" 26	11 a.m.		16.	61.	10.5	105.6	
							10.3	103.6	Just above junction with Des Plaines
Illinois River....	Morris	" 27	10.a.m.		17.	63.	1.8	18.4	
							1.7	17.4	Midstream
" "	"	" 27	10 a.m.		17.	63.	3.7	37.9	
							3.6	36.8	South side
" "	"	" 27	10:30 a.m.		17.	63.	1.8	18.4	
							1.7	17.4	North side
" "	Marseilles.	" 27	1:30 p.m.		17.	63.	2.1	21.5	
							2.3	23.6	Above dam
" "	"	" 27	3 p.m.		17.	63.	*A* 4.3	44.1	
							4.4	45.1	Below dam
							B 3.8	39.	

(*Note.*—These samples below dam are very unsatisfactory, as they were taken from shore near algæ.)

TABLE OF DISSOLVED OXYGEN AND CARBON DIOXIDE, ILLINOIS RIVER AND RELATED WATERS, 1911 AND 1912 — *Continued*

Water	Location	Date	Hour	Depth of sample	Water Temp. C.	Water Temp, F.	Dissolved Oxygen, p.p.m.	Dis. oxygen % sat'n.	Remarks
Illinois River ...	Starved Rock	Sept. 28	8:30 a.m.		17.	63.	5.3	54.3	
							5.1	52.3	North shore
" " ...	" "	" 28	8 a.m		16.	61.	4.8	48.3	
							4.6	46.3	South shore
Illinois River	Marseilles.	Oct. 11	10:30 a.m.		16.	61.	1.	10.1	
							.9	9.	Above dam; midstream
" "	Starved Rock....	" 11	2:30 p.m.		16.	61.	3.5	35.2	
							3.4	34.2	
							3.6	36.2	South shore
" "	" " ...	" 11	3 p.m.		16.	61.	4.8	48.2	
							4.7	47.2	North shore
" "	Hennepin	" 12	10 a.m.		15.	59.	5.5	54.2	
							5.6	55.2	Midstream
" " . ..	Chillicothe.	" 24	9:30 a.m.		12.	54.	6.5	60.	
							6.4	59.1	
							6.3	58.2	Midstream
" "	Hennepin	" 24	4:30 p.m.		12.	54.	6.3	58.2	
							6.5	60.	
							6.4	59.1	Midstream
" "	Chillicothe.	" 25	2 p.m.		12.	54.	6.	55.4	
							6.2	58.2	Midstream
" " . ..	Starved Rock...	" 26	9:30 a.m.		10.5	51.	6.1	54.5	
							6.2	55.4	North side
" "	" "	" 26	10 a.m.		11.	52.	5.	45.1	South side

TABLE OF DISSOLVED OXYGEN AND CARBON DIOXIDE, ILLINOIS RIVER AND RELATED WATERS, 1911 AND 1912 — *Continued*

Water	Location	Date	Hour	Depth of sample	Water Temp. C.	Water Temp. F.	Dissolved oxygen, p.p.m.	Dis. oxygen % sat'n.	Remarks
Drainage Canal..	Lockport	Nov. 1	5 p.m.		9.	49.	.4	3.5	9th st. bridge
Des Plaines R...	"	" 1	5:30 p.m.		9.	49.	4.5		
							4.6	38.8	" " "
Illinois River....	Morris.....	" 2	7:30 a.m.		9.	49.	4.8	41.4	North side
" " ...	"	" 2			9	49.	6.5	56.	South side
" " ...	Marseilles.....	" 2	10 a.m.		9.	49.	4.7		
							4.6	39.9	Above dam
Fox River.....	Ottawa	" 2	2:30 p.m.		6.5	44.	10.8		
							11.1		
							11.	81.4	
Illinois River....	"	" 2	3:30 p m.		9.	49.	5.8		
							5.7	49.1	Above Fox River
" "	Hennepin.....	" 3	10 a.m.		8.	47.	7.2		
							7.	60.1	
" "	Chillicothe.	" 3	2:30 p.m.		8.	47.	7.6		
							7.8	64.8	
" " ...	Peoria.	" 4	8 a.m.		8.	47.	10.6		
							10.3	88.3	Above sewer outfalls
" "	"	" 4	10 a.m.		8.	47.	9.5		
							9.6		
							9.7	80 8	Below all distilleries and sewers
" "	Havana.....	" 4	2 p.m.		8.	47.	9.7		
							9.6		
							9.4	80.8	
" "	Beardstown.....	" 5	9:30 a.m.		8.	47.	9.5		
							9.1		
							9.4	78.5	
" " ...	Pearl	" 6	1:30 p.m.		9.	49.	10.7		
							10.4	90.6	

Water	Location	Date	Hour	Depth of sample	Water Temp. C.	Water Temp. F.	Dissolved oxygen, p.p.m.	Dis. oxygen % sat'n.	Remarks
Illinois River	Grafton.....	Nov. 7	11 a.m.		9.	49.	9.		
							9.1	77.9	At mouth
Mississippi R....	"	" 7	12 m.		9.	49.	10.6		
							10.9	92.1	Above mouth of Illinois
Chicago River...	Chicago.....	" 12	9 a.m.		11.	52.	9.9		
							10.1	90.2	Halsted and 39th sts.
" " ...	"	" 12	9:30 a.m.		11.	52.	9.7	87.5	"Forks," east and west forks of south arm of south branch of Chicago River.
" " ...	"	" 12	9:45 a.m.		11.	52.	5.4	48.7	Bridgeport, south arm at junction with south branch of Chicago R.
Ogden ditch.	Chicago....	" 12	10 a.m.		10.5	51.	8.9	79.5	At Western avenue
	"	" 12	11:30 a.m.		10.	50.	8.8	75.9	South branch at Loomis street
	"	" 12	12 m.		9.5	50.	10.6	92.3	South branch at Van Buren street
Lake Michigan ..	Chicago.....	" 12	12:30 p.m.		9.	49.	12.4		
							12.1	105.2	Opposite U.S. Life Saving Station
	"	" 12	1 p.m.		10.3	50.6	6.7	59.9	North branch, Chicago avenue
	"	" 12	1 p.m.		10.	50.	8.9	88.7	North branch, North av.
	"	" 12	1:15 p.m.		10.5	51.	10.		
							9.8	87.7	North branch, Diversey Boulevard

TABLE OF DISSOLVED OXYGEN AND CARBON DIOXIDE, ILLINOIS RIVER AND RELATED WATERS, 1911 AND 1912 — *Continued*

Water	Location	Date	Hour	Depth of sample	Water Temp. C.	Water Temp. F.	Dissolved oxygen, p.p.m.	Dis. oxygen % sat'n.	Remarks
	Chicago	Nov. 12	1:30 p.m.		10.	50.	10.	87.1	North branch, ½ mi. below Lawrence avenue
Drainage Canal..	"	" 13	12 m.		11	52.	7.	63.1	Kedzie avenue
" " ..	Summit.....	" 13	1 p.m.		10.	50.	7.	62.	Santa Fe bridge
" " ..	Willow Springs..	" 13	1:30 p.m.		10.	50.	5.	44.3	
" " ..	Lemont	" 13	2 p.m.		10.	50.	3.1	27.4	
" " ..	Lockport.....	" 13	3 p.m.		10.	50.	2.2	19.5	9th st. bridge
" " ..	"	" 13	3:30 p.m.		10.	50.	2.8	24.7	At locks
Illinois River	Morris.....	" 14	7:30 a.m.		8.	47.	6.5	54.6	North side
" " ...	"	" 14	7:30 a.m.		8.	47.	6.8	57.2	Midstream
" "	"	" 14	7:30 a.m		8.	47.	8 7	73.1	South side
Mazon Creek. ...		" 14	7:30 a.m.		9.	49.	8.2	70.8	At mouth
Illinois River		" 14	8 a.m.		8.5	48.	6.2	53.	Kinney's Island
" "		" 14	8 a.m.		8.5	48.	5.4	46.2	Perry's Island, north side
" "		" 14	8:30 a m.		8.	47.	6.1	51.3	Perry's Island, midstream
" "		" 14	8:30 a.m.		8.	47.	9.5	80.	Perry's Island, south side
Au Sable Creek..		" 14	9 a.m.		5.5	42.	10.6	83.9	At mouth
Illinois River ..		" 14	9:30 a m.		7.	45.	4.5	36.9	At E. J. & E. R. R. bridge
" "	Dresden Heights.	" 14	11 a.m.		7.	45.	4.6	37.7	North side
" " ..	" " .	" 14	11 a.m.		6.	43.	11.3	90.5	South side
Des Plaines R...	" " .	" 14	11 a.m.		7.	45.	4.9	40.3	At mouth
Kankakee River.	" " .	" 14	11 a.m.		6.	43.	11.		
							10.8	87.2	At mouth
Illinois River...	Marseilles.	" 14	4 p.m.		8.	47.	7.7		
							8.	66.4	Above dam
Ill. & Michigan Canal	LaSalle..... ..	" 15	9 a.m.		4.5	40.	11.6		
							11.5	77.1	Lowest lock

TABLE OF DISSOLVED OXYGEN AND CARBON DIOXIDE, ILLINOIS RIVER AND RELATED WATERS, 1911 AND 1912 — *Continued*

Water	Location	Date	Hour	Depth of sample	Water Temp. C.	Water Temp. F.	Dissolved oxygen, p.p.m.	Dis. oxygen % sat'n.	Remarks
Ill. & Michigan Canal	LaSalle	Nov. 15	9:15 a.m.		4.5	40.	9.7	74.9	At mouth
Illinois River	Starved Rock	" 15	9:30 a.m.		5.5	42.	8.6	68.1	Above Vermilion River
Vermilion River		" 15	9:45 a.m.		4.5	40.	12.5		
							12.7	97.1	At mouth
Illinois River	LaSalle	" 15	10 a.m.		5.5	42.	9.		
							8.9	70.7	Highway bridge, 1 mile below Vermilion River
" "	Peru	" 15	11 a.m.		6.	43.	8.8		
							9.	71.3	
" "	Spring Valley	" 15	11:30 a.m.		6.	43.	9.		
							8.9	71 3	
" "	Marquette	" 15	12:15 p.m.		6.	43.	9.1	72.8	
Hennepin Canal		" 15	12:45 p.m.		7.	45.	13.1		
							13.	106.	At lowest lock
Illinois River		" 15	1 p.m.		6.	43.	9.		
							8.9	71.3	At mouth of Hennepin Canal
" "	Hennepin	" 15	2:30 p.m.		6.5	44.	8.7		
							8.8	70.7	
" "		" 15	3 p.m.		6.5	44.	8 5		
							8.7	69.9	Twin Sister Island
Mud Lake		" 15	3:30 p.m.		5.5	42.	12.9	102.	1,000 ft. from Ill. River
Illinois River		" 15	3:30 p.m.		6.5	44.	8.8		
							8.6	70.8	Opposite Mud Lake
" "	Henry	" 15	4 p.m.		6.5	44.	8.9		
							9.1	73.3	Above dam

TABLE OF DISSOLVED OXYGEN AND CARBON DIOXIDE, ILLINOIS RIVER AND RELATED WATERS, 1911 AND 1912 — *Continued*

Water	Location	Date	Hour	Depth of sample	Water Temp. C.	Water Temp. F.	Dissolved oxygen. p.p.m.	Dis. oxygen % sat'n.	Remarks
Illinois River	Henry	Nov. 15	4 p.m.		7.	45.	9.1		
							9.2	64.7	Below dam
" "	"	" 16	10 a.m.		5.5	42.	8.7	69.	Opposite wharf
" " ...	Lacon	" 16	11:15 a.m.		5.5	42.	8.5	67.3	
" "	"	" 16	12 m.		6.5	44.	8.9	72.3	Opposite Babb's Slough
" "	Chillicothe.	" 16	1:15 p.m.		6.5	44.	8.9		
							8.6	70.9	
" " ...	Peoria	" 16	1:30 p.m.		6.5	44.	9.2		
							9.1	74.	North end of Peoria Lake
Peoria Lake. ...	"	" 16	1:30 p.m.		6.5	44.	9.2	74.8	Partridge Island. west side
" "	"	" 16	1:45 p.m.		6.5	44.	9.7		
							9.2	75.5	Partridge Island, middle
" "	"	" 16	2 p.m.		6.5	44.	10.2	82.9	Partridge Island, east side
" "	"	" 16	2:30 p.m.		6.5	44.	9.8		
							9.6	78.9	Opposite Spring Bay
" "	"	" 16	3 p.m.		7.	45.	9.9	81.1	Below Horsor Slough, west side
" "	"	" 16	3 p.m.		7.	45.	9.5	77.9	Below Horsor Slough, mid-stream
" "	"	" 16	3 p.m.		7.	45.	10.8	88.6	Below Horsor Slough, east side
" "	"	" 16	3:30 p.m.		7.	45.	9.7		
							9.9	80.3	Opposite Peoria Heights
" "	Averyville.	" 16	3:45 p.m.		6.	43.	9.9	79.3	West side
" "	"	" 16	3:45 p.m.		6.5	44.	10.4		
							10.1	83.	Midstream
" "	"	" 16	3:45 p.m.		6.	43.	11.	88.1	East side
Illinois River....	Peoria ..., ...	" 16	4 p.m.		6.	43.	10.6	84.1	At Liberty street, near shore

Water	Location	Date	Hour	Depth of sample	Water Temp. C.	Water Temp. F.	Dissolved oxygen, p.p.m.	Dis. oxygen % sat'n.	Remarks
Illinois River ..	Peoria	Nov. 16	4 p.m.		6.	43.	10.3	82.5	At Libertystreet, midstream
" " ...	"	" 17	8:45 a.m.		6.	43.	9.3		
							9.8	76.	Below distilleries
" "	Pekin	" 17	9:30 a.m.		6.	43.	9.6		
							9.8	77.7	
" "	"	" 17	10 a.m.		5.5	42.	9.7		
							9.6	76.	Below distilleries
" " ...		" 17	10:15		5.5	42.	9.7		
							9.8	76.6	Opposite Mackinaw River
" " ...	Kingston Mines .	" 17	10:30		5.5	42.	10.		
							9.8	78.5	
" "	Copperas Creek.	" 17	11:30		5.5	42.	10.1		
							10.	79.	Above dam
" " ...	" " ..	" 17	11:30		5.8	42.6	10.1	80.9	Below dam
" "	Liverpool.....	" 17	12:30		5.8	42.6	9.6		
							9.9	77.7	
Spoon River....		" 17	4 p.m.		4.5	40.	12.		
							11.9	92.3	At mouth
Illinois River...	Havana	" 17	4 p.m.		6.	43.	9.8		
							9.6	77.6	
" "		" 18	9:45 a.m.		5.	41.	10.1		
							9.8	77.3	Above Grand Island
" " ...		" 18	11 a.m.		5.3	41.6	10.1	79.9	Below Grand Island
" " ...	Sharp's Landing.	" 18	11:30		5.3	41.6	10.		
							9.9	78.4	
" " ...	Browning.....	" 18	12:30		5.5	42.	10.4	82.5	
" "	Beardstown	" 18	2 p.m.		6.	43.	10.2		
							10.	80.9	

TABLE OF DISSOLVED OXYGEN AND CARBON DIOXIDE, ILLINOIS RIVER AND RELATED WATERS, 1911 AND 1912 — *Continued*

Water	Location	Date	Hour	Depth of sample	Water Temp. C.	Water Temp. F.	Dissolved oxygen, p.p.m.	Dis. oxygen % sat'n.	Remarks
Crooked Creek...		Nov. 18	2:45 p.m.		5.	41.	10.4	81.3	At mouth
Illinois River....		" 18	3 p.m.		5.8	42.6	10.7		
							10.5	84.8	Opposite Crooked Creek
" "	LaGrange	" 18	3:30 p.m.		6.	43.	9.8		
							10.1	79.4	Above dam
" "	"	" 18	3:45 p.m.		6.	43.	10.		
							10.3	81.8	Below dam
" "	Meredosia	" 19	7:15 a.m.		5.	41.	10.8		
							10.7	83.5	
" "	Naples	" 19	7:45 a.m.		5.	41.	10.9		
							11.	85.2	
" "	Valley City.....	" 19	8:30 a.m.		5.5	42.	10.8		
							10.6	84.7	
" "	Florence	" 19	9 a.m.		5.5	42.	10.7		
							10.5	84.1	
" "	Bedford	" 19	9:45 a.m.		5.5	42.	10.9	86.2	
" "	Pearl	" 19	10:30		5.8	42.6	11.5	92.	
" "	Kampsville	" 19	1 p.m.		6.	43.	11.1		
							11.2	88.9	Above dam
" "	"	" 19	1:15 p.m.		6.	43.	10.8	86.5	Below dam
" "		" 19	2 p.m.		6.	43.	10.9		
							10.6	85.7	Head of Diamond Island
" "	Hardin, ...	" 19	2:20 p.m.		7.	45.	11.3		
							11.4	92.7	
" "		" 19	3:10 p.m.		6.8	44.6	10.9		
							11.5	91.8	Above Twelve Mile Island
" "		" 19	4:30 p.m.		6.5	44.	10.8		
							10.7	87.	At mouth
Mississippi R....	Grafton..	" 19	4:45 p.m.		6.5	44.	13.4		
							13.8	112.	West side
" "	"	" 19	4:50 p.m.		6.	43.	14.4		
							14.1	114.	Midstream
" "	"	" 19	5 p.m.		6.5	44.	11.		
							10.9	88.2	East side

EXPLANATION OF PLATES

Plate LXV

Upper Illinois River and principal tributaries.

Plate LXVI

Fig. 1. Des Plaines River and Sanitary Canal at Lockport
Fig. 2. Illinois River at Marseilles.

ERRATA

Page 497, line 9 from bottom, for *neglible* read *negligible,* and in footnote, for *Austalt* read *Anstalt.*

Page 498, line 4 from bottom, for *Lockport* read *Chillicothe.*

Page 500, line 13 from bottom, after *up* insert *in.*

Page 501, line 2 from bottom, for *dissolving* read *dissolved.*

Page 504, line 23, for *gryina* read *gyrina.*

Page 506, line 11, for *vernata* read *ternata.*

Page 507, line 3 from bottom, for *Mazon* read *wagon.*

Page 513, line 19, for *Nepa* read *Zaitha.*

Page 525, line 22, and page 536, lines 21 and 24, for Ekmann read Ekman.

Page 532, line 1, for *Ancyclus* read *Ancylus.*

Page 551, line 7, for *00* read *512.*

Plate LXXXV, for *7* read *7c.*

Plate LXXVII

View of Flag Lake, 1910.

Plate LXXVIII

Permanent overflow of Illinois River bottoms near Havana.

Plate LXXIX

Characteristic views from the middle course of the Illinois.

Water	Loca	Remarks
Crooked Creek...		h
Illinois River		Crooked Creek
" "	LaGrang	am
" "	"	ım
" "	Meredosi	
" "	Naples ..	
" "	Valley Ci	
" "	Florence	
" "	Bedford .	
" "	Pearl	
" "	Kampsvil	
" "	"	ım
" "		ım
" "	Hardin..	Diamond Island
" "		
" "		welve Mile Island
Mississippi R....	Grafton..	h
" "	" ..	le
" "	" ..	.m
		e

EXPLANATION OF PLATES

Plate LXV

Upper Illinois River and principal tributaries.

Plate LXVI

Fig. 1. Des Plaines River and Sanitary Canal at Lockport.
Fig. 2. Illinois River at Marseilles.

Plate LXVII

Illinois River at Morris.

Plate LXVIII

Marseilles Dam, June 15, 1901. View from north end.

Plate LXIX

Marseilles Dam, July 22, 1906. View from south end.

Plate LXX

South bank of Illinois River, below Ottawa.

Plate LXXI

In Horse-shoe Cañon, near Ottawa.

Plate LXXII

Illinois River bluff, immediately above Starved Rock.

Plate LXXIII

The Valley of the Illinois, from Starved Rock.

Plate LXXIV

The Valley of the Illinois, from Prospect Heights, above Peoria.

Plate LXXV

Sketch of waters near Havana, 1911.

Plate LXXVI

The Illinois River and bottom-land lakes, from Havana, 1910.

Plate LXXVII

View of Flag Lake, 1910.

Plate LXXVIII

Permanent overflow of Illinois River bottoms near Havana.

Plate LXXIX

Characteristic views from the middle course of the Illinois.

Plate LXXX

Fig. 1. Illinois River levels, Havana. Monthly means, 1897-98 and 1909-10.
Fig. 2. Dissolved oxygen, Kankakee, upper Illinois, and Des Plaines rivers. midsummer of 1911.

Plate LXXXI

Fig. 1. Dissolved oxygen, Illinois River. November data.
Fig. 2. Dissolved oxygen, Illinois River. Winter and midsummer data.

Plate LXXXII

Fig. 1. *Eristelis tenax*, after Miall.
Fig. 2*a*-2*e*. *Hyalella knickerbockeri*: 2*a*, entire animal; 2*b*, first cheliped; 2*c*, first uropod; 2*d*, second uropod; 2*e*, telson, (U. S. Geol. and Geogr. Surv. of the Territories, 1873.)
Fig. 3. Slime worms, *Tubifex*, after Kolkwitz.
Fig. 4. *Rotifer actinurus*, after Kolkwitz.
Fig. 5. *Colpidium colpoda*, after Kolkwitz.
Fig. 6. *Paramecium putrinum*, after Kolkwitz.

Plate LXXXIII

Fig. 1. *Paramecium caudatum*, after Blochman.
Fig. 2. *Vorticella microstoma*, after Blochman.
Fig. 3. *Epistylis plicatilis*, after Blochman.
Fig. 4. *Carchesium lachmanni*, after Kent.
Fig. 5. *Anthophysa vegetans*, after Blochman.
Fig. 6. *Anthophysa vegetans*, after Kent.
Fig. 7. *Chlamydomonos monadina*, after Blochman.
Fig. 8. *Oikomonas termo*, after Blochman.
Fig. 9. *Bodo saltans*, after Kolkwitz.
Fig. 10. *Stigeoclonium tenue*, after Kirchner.

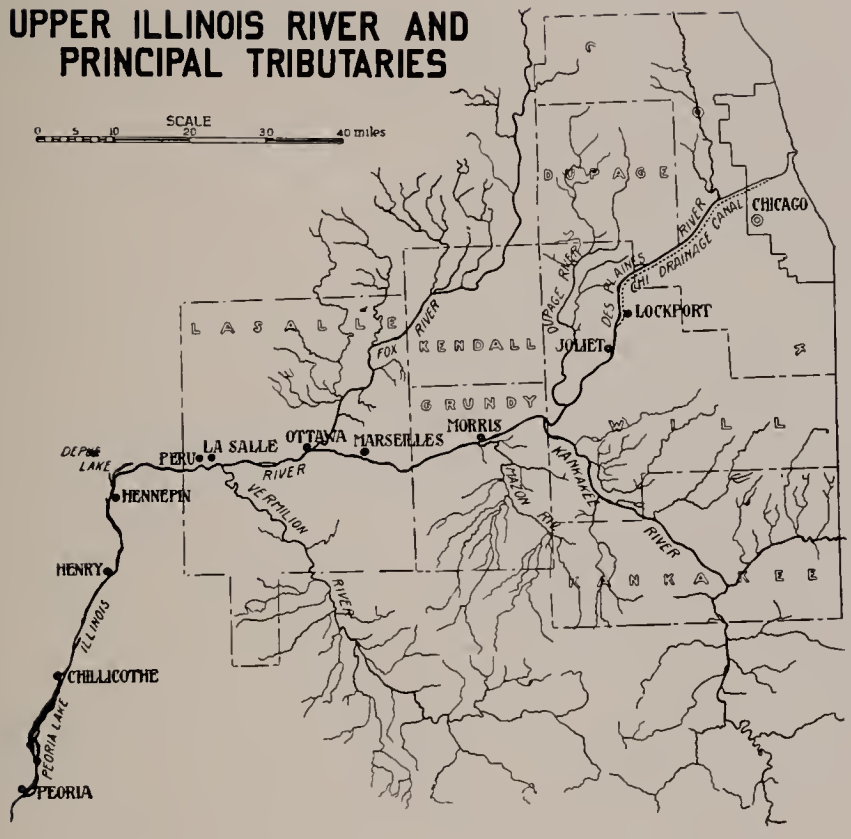
Plate LXXXIV

Fig. 1. *Chætophora elegans.*
Fig. 2. *Microthamnion kützingianum*, after Kirchner.
Fig. 3. *Cladophora crispata*, after Kolkwitz.
Fig. 4. *Cladophora glomerata*, after Kolkwitz.
Fig. 5. *Schizomeris leibleinii.* Tufts College Studies, Vol. II.
Fig. 6. *Ulothrix zonata.*
Fig. 7*a*-7*c*. *Chlorella vulgaris.* Rev. Gen. Botanique, Tome XV.
Fig. 8. *Lyngbya versicolor.* Minn. Algæ, Vol. I.
Fig. 9. *Phormidium uncinatum.* Minn. Algæ, Vol. I.
Fig. 10. *Oscillatoria limosa*, after Kolkwitz.

Plate LXXXV

Fig. 1. *Cyclotella kützingiana*, after Kirchner.
Fig. 2. *Fragilaria virescens*, after Kirchner.
Fig. 3. *Tabellaria flocculosa*, after Kolkwitz.
Fig. 4. *Tabellaria fenestrata*, after Kirchner.
Fig. 5. *Melosira varians*, after Kolkwitz.
Fig. 6*a*, 6*b*. *Sphærotilus natans*, after Kolkwitz.
Fig. 7*a*, 7*c*. *Cladothrix dichotoma*, after Kolkwitz.
Fig. 7*b*. *Cladothrix dichtoma*, after Kirchner.
Fig. 8. *Beggiatoa alba*, after Kolkwitz.

PLATE LXV


UPPER ILLINOIS RIVER AND
PRINCIPAL TRIBUTARIES
SCALE
0 5 10 20 30 40 miles
DUPAGE
CHICAGO
DES PLAINS RIVER
CHI DRAINAGE CANAL
DUPAGE RIVER
LOCKPORT
JOLIET
LA SALLE
FOX RIVER
KENDALL
GRUNDY
MORRIS
OTTAWA
MARSEILLES
LA SALLE
PERU
DEPUE LAKE
RIVER
HENNEPIN
VERMILION
RIVER
MAZON RIV.
NAMAKEE
RIVER
WILL
KANKAKEE
HENRY
ILLINOIS
CHILLICOTHE
PEORIA LAKE
PEORIA

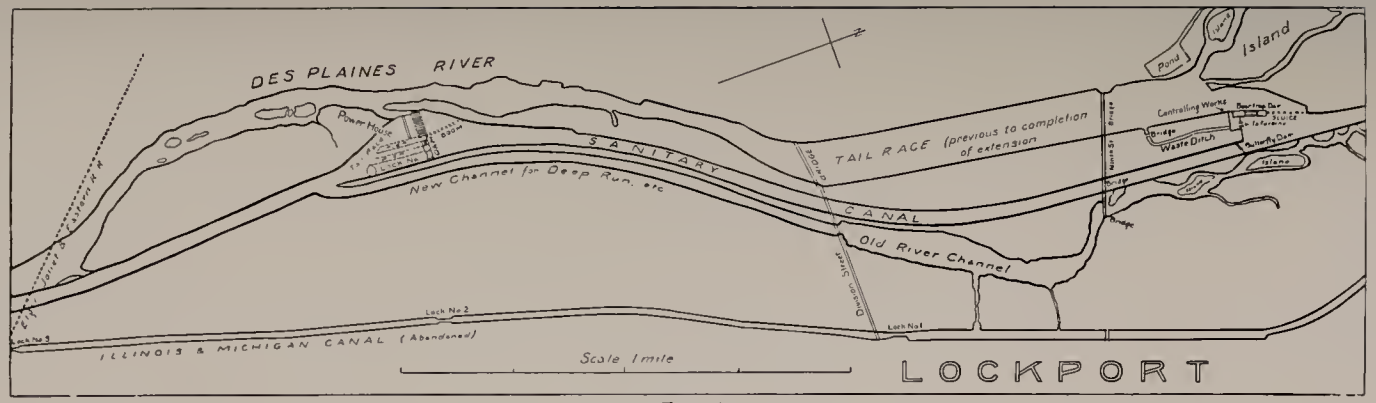


FIG. 1

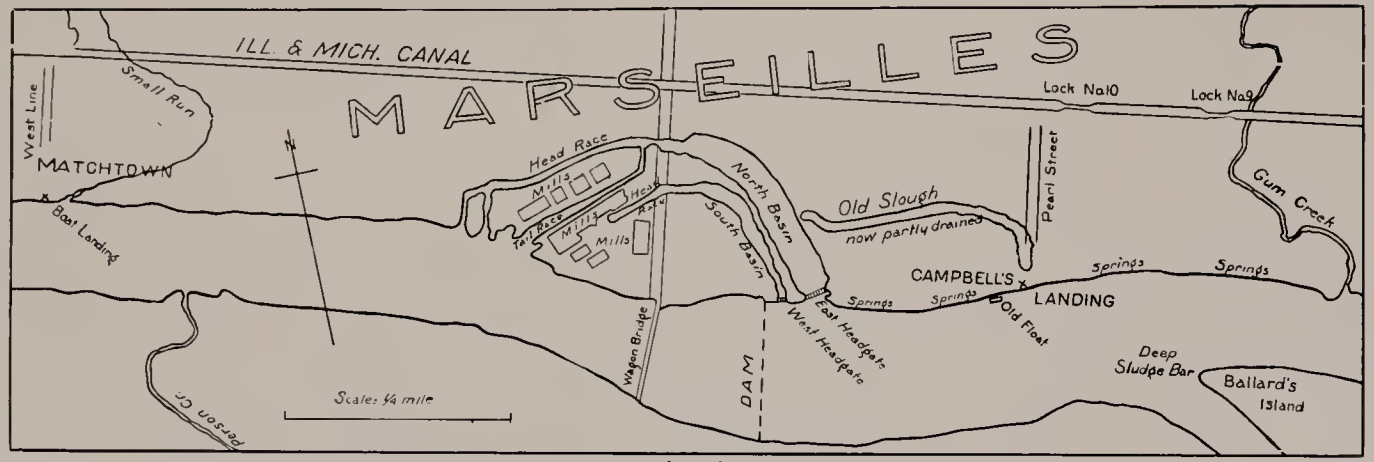


FIG. 2

PLATE LXVI

PLATE LXVII

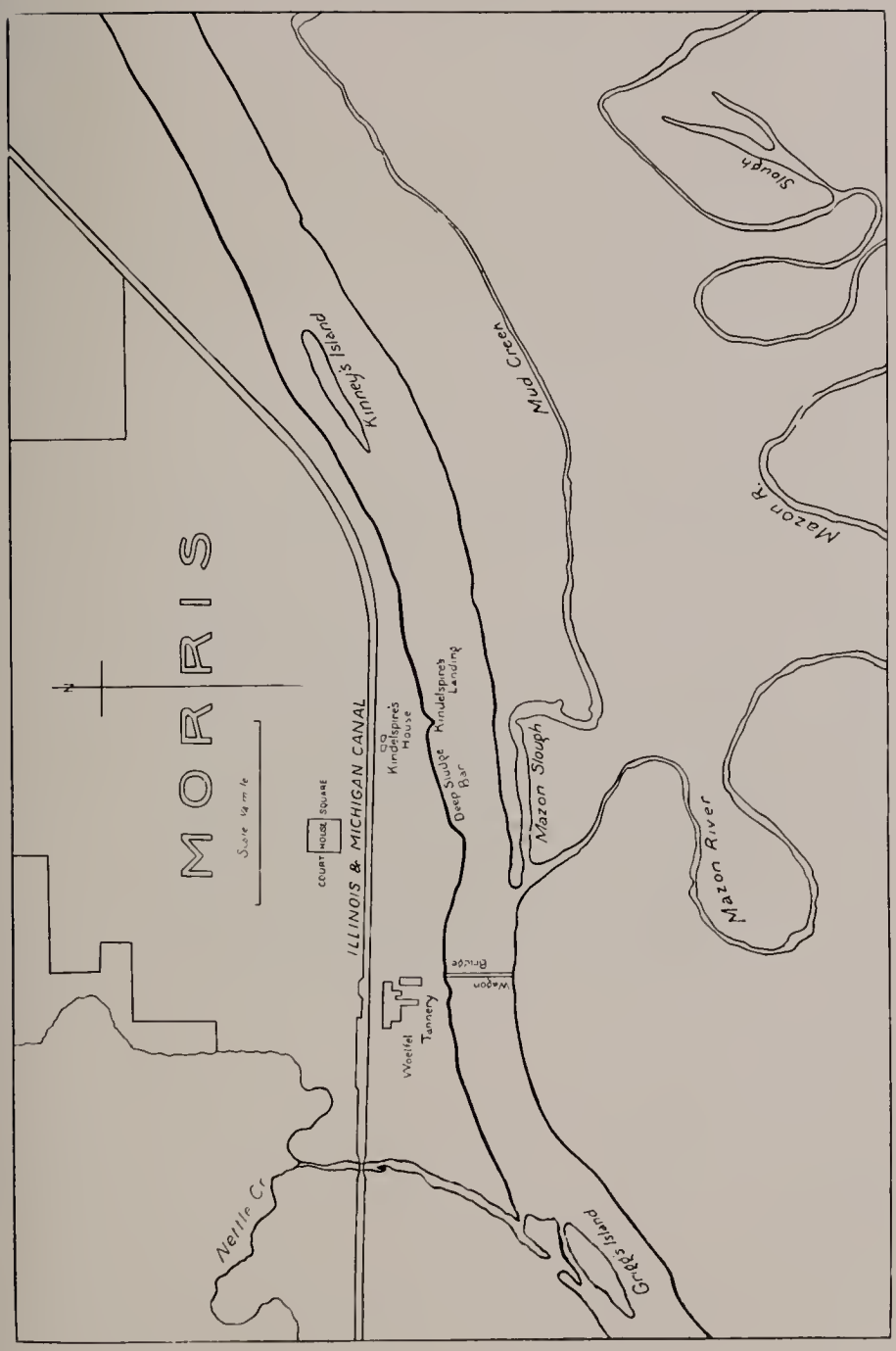

MORRIS
Scale ½ m le
COURT HOUSE SQUARE
ILLINOIS & MICHIGAN CANAL
Kinney's Island
Mud Creek
Slough
Mazon R.
Kindelspire's House
Kindelspire's Landing
Deep Swale
Deep Bar
Mazon Slough
Mazon River
Bridge
Mazon
Woelfel Tannery
Nettle Cr
Grade's Island

PLATE LXVIII

PLATE LXIX

PLATE LXX

PLATE LXXI

PLATE LXXII

PLATE LXXIII

PLATE LXXIV

SKETCH OF WATERS NEAR HAVANA, 1911

PLATE LXXVI

PLATE LXXVII

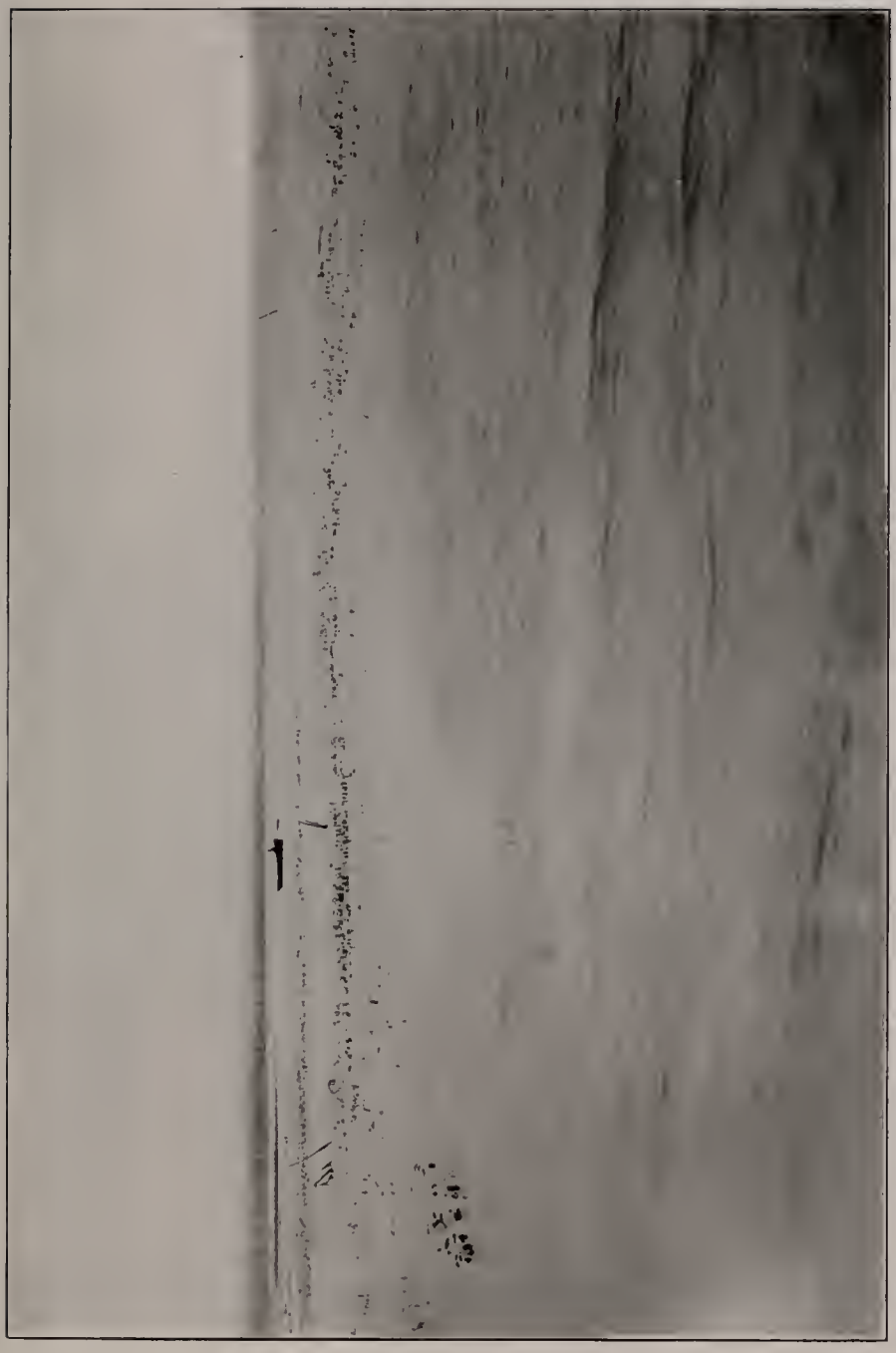


PLATE LXXVIII

PLATE LXXIX

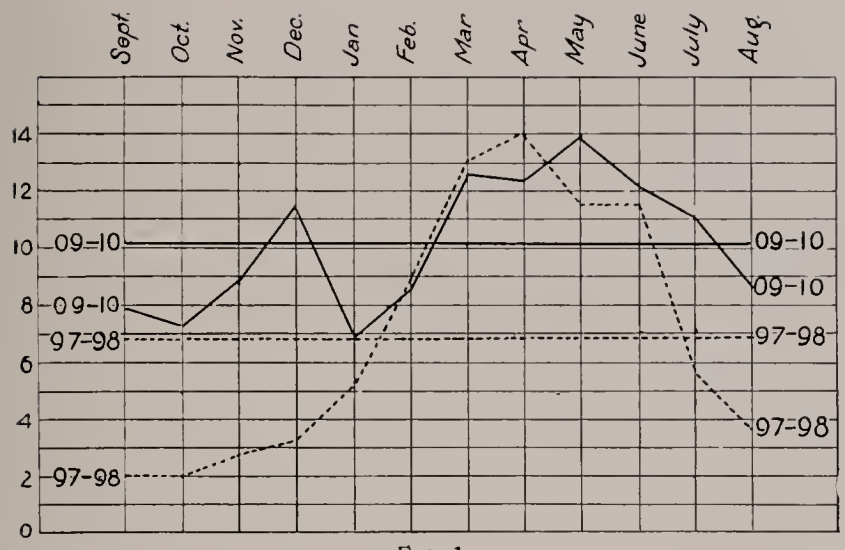

Sept.
Oct.
Nov.
Dec.
Jan
Feb.
Mar
Apr
May
June
July
Aug.
14
12
10
8
6
4
2
0
09-10
09-10
09-10
09-10
97-98
97-98
97-98
97-98

FIG. 1

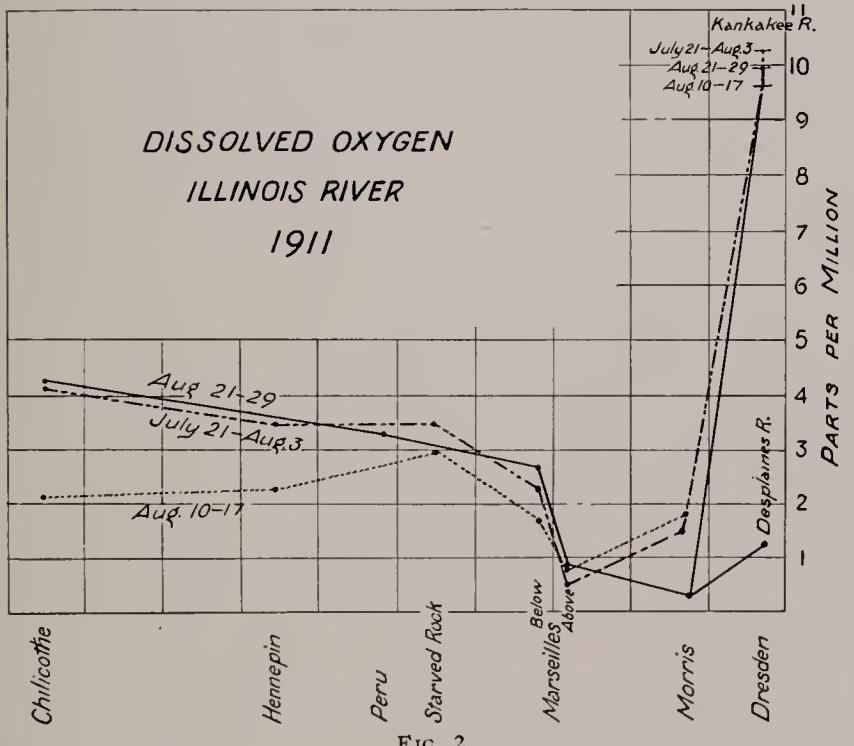

DISSOLVED OXYGEN
ILLINOIS RIVER
1911
Kankakee R.
July 21-Aug. 3
Aug. 21-29
Aug. 10-17
Aug. 21-29
July 21-Aug. 3
Aug. 10-17
Des Plaines R.
PARTS PER MILLION
11
10
9
8
7
6
5
4
3
2
1
Chillicothe
Hennepin
Peru
Starved Rock
Below
Above
Marseilles
Morris
Dresden

FIG. 2

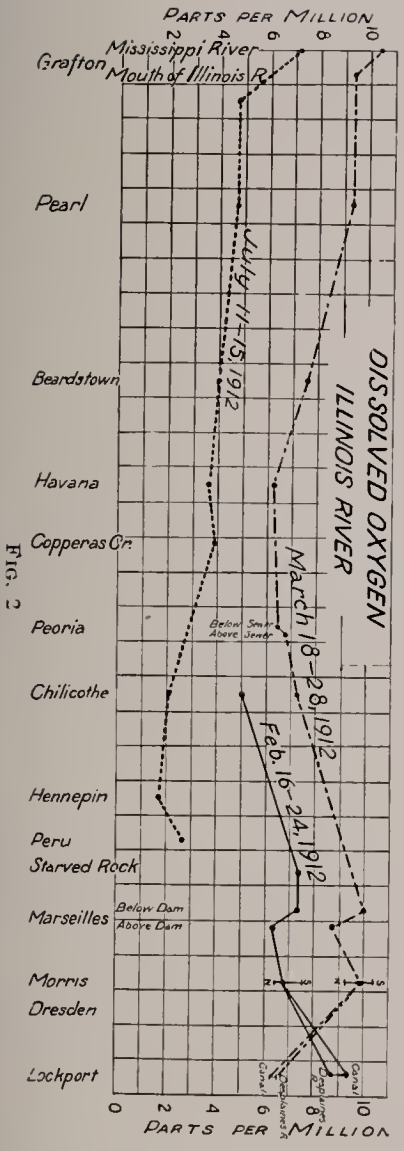

PARTS PER MILLION
Grafton
Mississippi River
Mouth of Illinois R.
Pearl
Beardstown
Havana
Copperas Cr.
Peoria
Below Sewer
Above Sewer
Chilicothe
Hennepin
Peru
Starved Rock
Marseilles
Below Dam
Above Dam
Morris
Dresden
Lockport
Deaplaines R.
Canal
July 11-15, 1912
March 18-28, 1912
Feb. 16-24, 1912
DISSOLVED OXYGEN
ILLINOIS RIVER
PARTS PER MILLION

Fig. 2

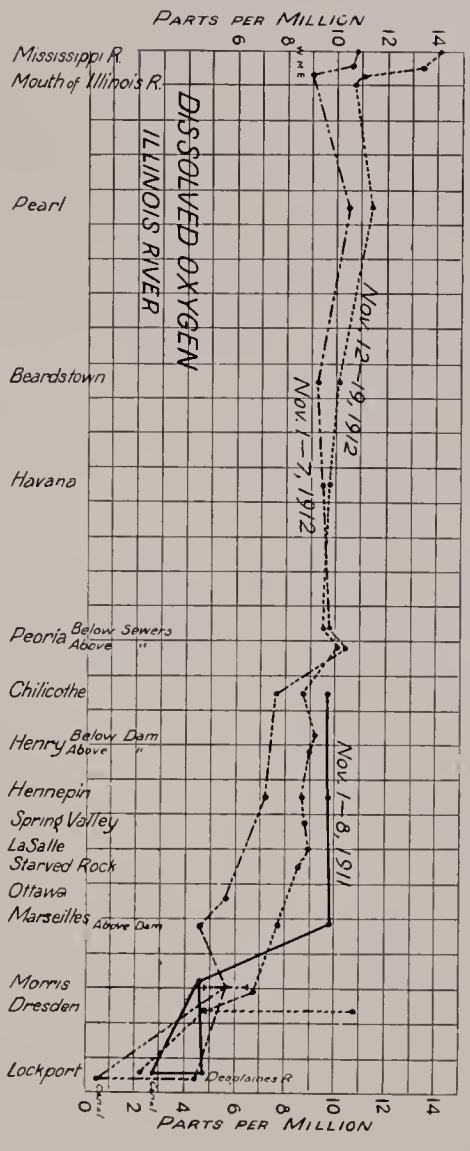
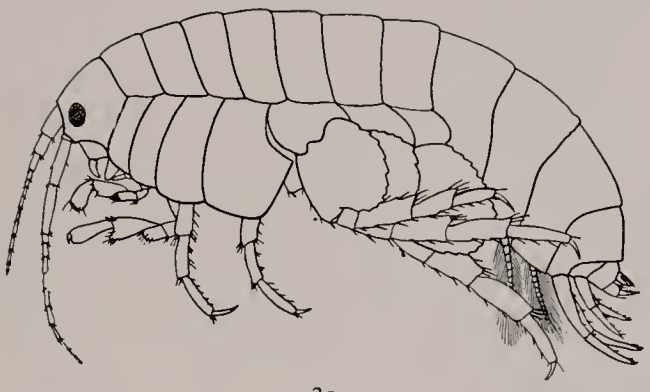

PARTS PER MILLION
Mississippi R.
Mouth of Illinois R.
Pearl
Beardstown
Havana
Peoria
Below Sewers
Above "
Chilicothe
Henry
Below Dam
Above "
Hennepin
Spring Valley
LaSalle
Starved Rock
Ottawa
Marseilles
Above Dam
Morris
Dresden
Lockport
Deaplaines R.
Canal
Nov. 12-19, 1912
Nov. 1-7, 1912
Nov. 1-8, 1911
DISSOLVED OXYGEN
ILLINOIS RIVER
PARTS PER MILLION

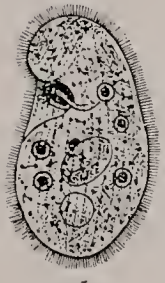
Fig. 1

PLATE LXXXII

1



2a



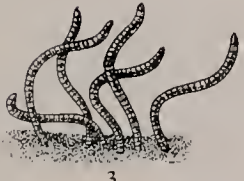
5

2b

2d

2e

4



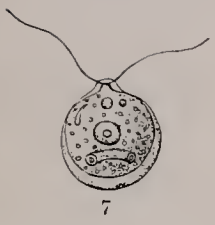
3

6

2c

Plate LXXXIII

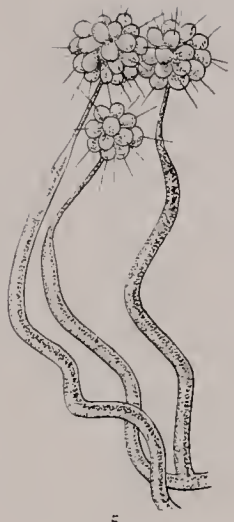
1



7

9

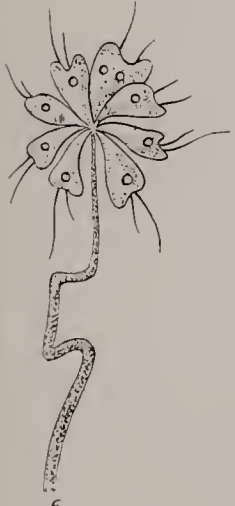
4



5

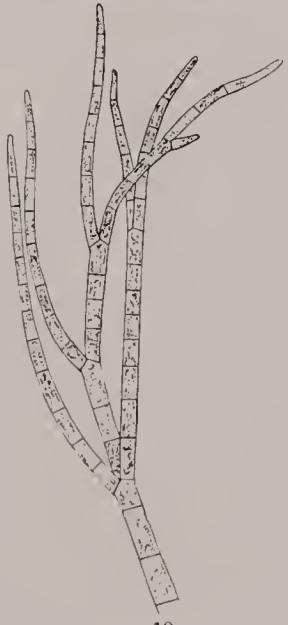
2

8



6

3



10

PLATE LXXXIV

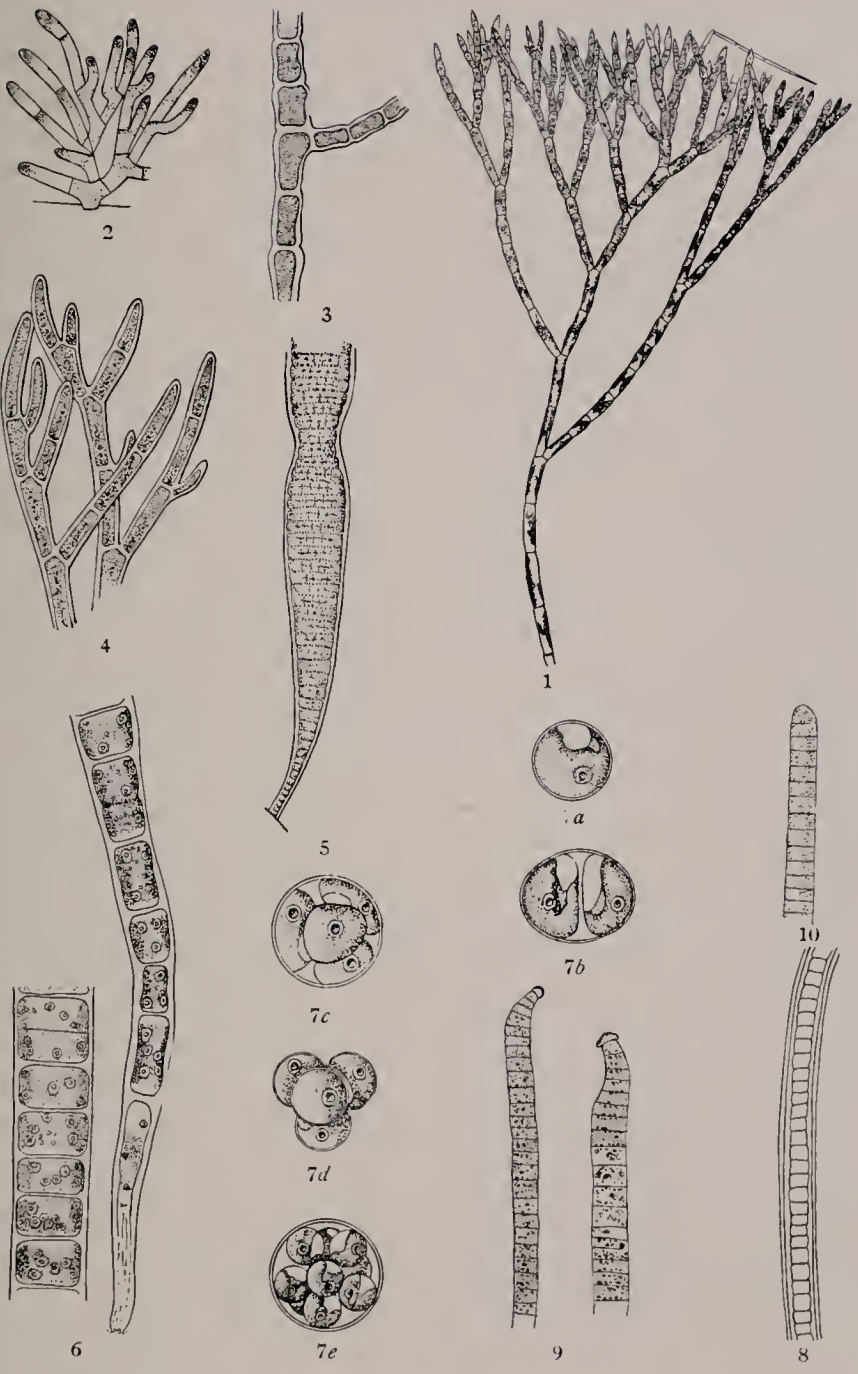
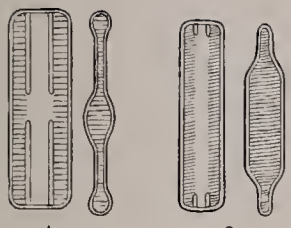
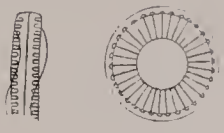


Plate LXXXV



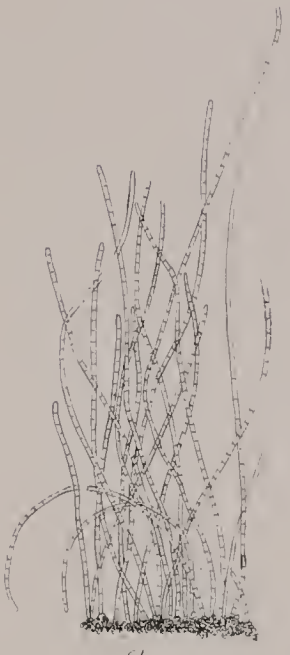
4 2



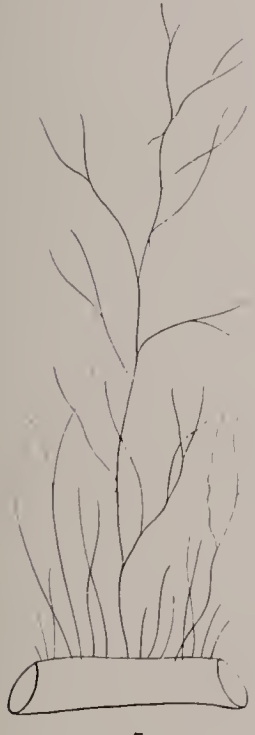
1

6a

3 5

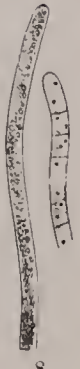


6b



7a

7b



8

7