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Some Observations on the Oxygen Requirements of Fishes in the Illinois River

BY

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ERRATA

Page 57, statistical headings: for *Year 1920* read *Year 1910;* for *Year 1909* read *Year 1920*; in the ratio heading, for *1909* read *1920*, and for *1920* read *1910*. The entries in the Year columns should change places.

Page 85, line 13 from bottom, for *87* read *86*.

Page 88, line 20, delete *red*.

Page 115, line 6, over the column of figures read *Acres*.

Page 136, line 5, for *135* read *131*.

Page 145, *First table*, 4th column, for *35.97* read *33.40;* last column, for .052 read .0418.

Second table, second column, for .2158 read .2004; 5th column, for .1131 read .0977; last column, for .0926 read .0772.

Last table, second column, for .714 read .663 and for total read $4.710; 5th column, for .374 read .323 and for total read $2.201; the last column, for .307 read .256 and for total read $1.700.

Page 146: *First table*, second column, for 8.02 read 7.45 and for total read 52.92; third column, for 3.45 read 2.88 and for total read 19.10; 4th column for 19.28 read 17.90 and for total read 127.18; last column, for 8.29 read 6.92 and for total read 46.35.

Second table, for 43.02 read 38.66.

Last table, for 8.0 read 6.7.

Page 382, line 10 from bottom, for *Platythemis* read *Plathemis*.

Page 385, in list, the specific names of No.'s 33, 35, and 40 should end in *us* instead of *a*.

Pages 445 (line 4), 448 (line 4), 449 (line 23), 454 (line 8 from bottom), read *Belostomidae* for *Belostomatidae*.

Page 457, line 21, for *cornutus* read *cornuta*.

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Article VII.—*Some Observations on the Oxygen Requirements of Fishes in the Illinois River.* By David H. Thompson.

Introduction

The amount of oxygen dissolved in the water is one of the most important factors limiting the fish life of the Illinois River. Every year low dissolved oxygen concentrations over a large portion of the river profoundly affect the food, distribution, and even the existence of the fishes. In the conservation of the Illinois River fishery it becomes necessary to evaluate the oxygen requirements of the more common fishes. The Illinois Natural History Survey and the State Water Survey have for many years conducted a biological and chemical survey of the Illinois River. As a result, the general oxygen conditions are rather completely known for the various parts of the river during the different seasons of the year, and the distribution of fishes is well enough understood to show the general relation to the range of oxygen concentrations. The present paper is the result of an attempt to determine more precisely the minimal oxygen requirements of the common fishes and some of the effects of low dissolved oxygen concentrations, especially in winter.

Dr. R. E. Greenfield and Mr. A. L. Sotier, of the State Water Survey, made a series of dissolved oxygen determinations on the river during the latter part of January, 1925. They reported that the fishes were crowding into the "spring holes" in Peoria Lake, evidently on account of unsuitable conditions in parts of the lake which were frozen over. The writer, accompanied part of the time by Mr. Sotier, spent the latter part of January and all of February gathering data on the fish life of the river and making dissolved oxygen determinations in places where fishes were being taken, where fishes were dying, and where fishes usually had been taken but were absent at the time on account of special conditions of the water. Much credit is due a number of fishermen for collateral information and for their co-operation in the field work.

Some valuable determinations of dissolved oxygen in the channel were made by the State Water Survey on January 23 and 24 and on February 6 and 7, 1925, which are published here for the first time.

The General Relation of Ice and Dissolved Oxygen

It is a common observation that fish often die in the winter under the ice. This has been noticed most often where the ice has completely covered the water for a considerable period. It is also commonly said by fishermen, in certain places, that when a hole is cut in the ice the fish will come to the place "to get air" and are very easily taken. It seems quite clear that the reason fish die under ice or come to holes in the ice is because there is a deficiency of dissolved oxygen in the water.

A layer of ice over a body of water very effectually prevents the interchange of gases between the water and the air. The ice itself does not decrease the amount of oxygen, but it stops the aeration of the water. The decrease in amount of dissolved oxygen is brought about by the oxidation of organic matter in the water. This organic matter does not oxidize directly, but it forms the food of the bacteria and of larger plankton—the immense numbers of minute plants and animals which utilize the oxygen in their life processes. As a result, the amount of dissolved oxygen that is removed from the water depends on the amount of organic matter present and on the rate at which this is consumed by aquatic organisms.

The life processes of these plants and animals which consume the oxygen go on very slowly in water that is cold enough to be covered with ice. It would seem that for this reason those lakes and very sluggish streams which are frozen over early and thaw out late would suffer most from the lack of oxygen. However, due to their sluggishness the solid organic matter settles to the bottom and can not quickly reduce the dissolved oxygen content of the whole body of water. In the deeper lakes fish do not die under the ice, probably because of the relative scantiness of organic matter and the greater amount of dissolved oxygen in the deeper water. In most streams large amounts of organic matter are constantly being added by drainage from the land and by wastes from cities. The stirring action of the current is usually sufficient to keep much of the solid organic matter in suspension and thus it exposes all parts of the stream to loss of oxygen. Some streams are so swift that they do not freeze over completely, and enough open water is left to keep the dissolved oxygen content of the water high enough for the life of fishes.

Recent Observations on the Relation of Ice and Dissolved Oxygen in the Illinois River

The Illinois River is not often covered with ice long enough for the oxygen dissolved in the water to be reduced to a point where the fish show signs of distress. The river froze over in December, 1924, and did not thaw out until the first week in February, 1925. It was completely covered with ice except for small patches of open water where the current was swiftest, notably in Peoria Narrows and below all bridges. Fishermen say that this is the first time the river has been frozen over for any considerable time since the winter of 1917-1918. Kofoid* states that during the winter of 1894-95 the river froze over the latter part of December and the ice did not go out until the last of February. This

* Bul. Ill. State Lab. Nat. Hist., 6:176, 1901.

ice was present during a prolonged period of low water, and it was accompanied by the almost complete disappearance of the plankton organisms and by the death of large numbers of fish. Although this occurred before the Chicago Drainage Canal was opened, it must be remembered that the Illinois River was even then a heavily polluted stream. At that time the volume of water carried was much smaller than at present and the rate of flow was slower. It seems probable that the river because of its slower current was more likely to freeze over then than now, but that this tendency was partially counteracted by greater changes in level which tended to break up the ice and keep the channel open.

During January and February, 1925, dissolved oxygen determinations were made in the Illinois River and related waters between La Salle and Meredosia. Table I shows the results of these determinations together with notes on ice conditions and temperature of the water. Since the river froze over before Christmas, it seems probable that when the field work was begun, January 23, dissolved oxygen concentration had reached its lowest point. Samples taken on January 23 and 24 showed about 1.7 parts per million of dissolved oxygen at Peoria Narrows, Pekin, and Havana, but those from Henry and La Salle showed about 6 parts per million. This is probably not because of better aeration up-stream but because the initial charge of oxygen dissolved in the water that diluted the sewage had, on account of the low temperature, not yet been consumed. It is quite probable that at this time the very low oxygen prevailed from Peoria Narrows to the mouth of the river at Grafton. On February 2, oxygen concentrations as low as 0.4 part per million were found in Mud Lake, which is partly fed by river water. Records of bullheads dying in the traps and seines in Treadway Lake and Coleman Lake indicate that low dissolved oxygen concentrations prevailed also in those backwaters that are fed by the river. A sample taken in the middle of Quiver Lake showed 2.3 parts per million of dissolved oxygen. This comparatively high figure is due to the highly oxygenated water coming out of Quiver Creek. On February 4 samples taken in Treadway Lake and Coleman Lake showed over 5 parts per million of dissolved oxygen. This high figure is brought about by the dilution of these lakes with Sangamon River water. By February 5, when the river channel was partly open, samples at Beardstown showed 3.3 and 3.7 parts per million of dissolved oxygen in mid-channel with 4.6 and 4.1 near the east bank, due to the better water coming out of Sangamon River. On February 6 and 7 there was much open water, but the water temperature was still between 0° and 4° C. Samples taken at Henry and Chillicothe showed about 5 parts per million of dissolved oxygen, which is somewhat lower than the up-stream samples taken two weeks previously; but the samples taken at Peoria Narrows and Pekin gave about 3 parts per million, almost twice the amount found on the earlier trip. The thawing continued until the channel was free of ice by February 8. On February 10 at Browning the channel showed 5.8 parts per million of dissolved oxygen. The next day at Beardstown it was 6.6.

TABLE I. THE RELATION OF ICE AND DISSOLVED OXYGEN IN THE ILLINOIS RIVER AND RELATED WATERS, 1925

Location	Miles above Grafton	Date 1925	Ice conditions	Water temp. C.	Sample taken from	Dissolved oxygen parts per million
Peoria Narrows, mid-channel	166	Jan. 23	Heavy ice everywhere except a little open water in the Narrows and below the bridge	0.5–1.5	Bottom	1.7
				"	Top	1.6
Henry, mid-channel	196	Jan. 23	A little open water below the bridge. Heavy ice elsewhere	"	Bottom	5.7
				"	Top	5.8
Henry, E. of channel	196	Jan. 23		"	Bottom	6.3
				"	Top	6.4
Pekin, mid-channel	153	Jan. 23	Completely frozen over except in the draw of the bridge	"	Bottom	1.7
				"	Top	1.7
Pekin, W. of channel	153	Jan. 23		"	Bottom	1.8
La Salle, mid-channel below wagon bridge	224	Jan. 24	Channel has been open 3-4 days. Some shore ice	"	Bottom	6.1
				"	Top	5.9
				"	Bottom	6.2
Havana, mid-channel	120	Jan. 24	All heavy ice except a little open water below bridge	"	Bottom	1.4
				"	Top	2.0
Clear Lake, Haven's Landing	132	Feb. 2	Completely covered with heavy ice	3.0	Bottom	1.7
Mud Lake, in the middle	132	Feb. 2	"	4.0	Bottom	0.4
				2.5	Top	1.2
Mud Lake, E. shore	132	Feb. 2	"	2.5	Middle	1.0
Quiver Creek	125	Feb. 3	All open water except a little shore ice	2.0	Bottom	11.4
				1.5	Top	11.1
Quiver Lake near mouth of Quiver Creek	125	Feb. 3	Open water about the mouth of Quiver Creek	1.0	Bottom	5.7
Quiver Lake, in the middle	124	Feb. 3	Covered with heavy ice	1.0	Bottom	2.3
Coleman Lake, in the middle	93	Feb. 4	"	2.0	Bottom	5.0
				1.0	Top	5.4
Treadway Lake, E. shore	93	Feb. 4	"	—	Bottom	5.0

TABLE I. (*Continued*)

Location	Miles above Grafton	Date 1925	Ice conditions	Water temp. C.	Sample taken from	Dissolved oxygen parts per million
Treadway Lake, in the middle	93	Feb. 4	Covered with heavy ice	—	Bottom	5.4
Phelps Ditch	92	Feb. 4	"	—	Bottom	1.5
Beardstown, E. of channel	88	Feb. 5	Channel partly open	4.0	Bottom	4.6
				4.0	Top	4.1
Beardstown, mid-channel	88	Feb. 5	"	4.0	Bottom	3.3
				3.9	Top	3.7
Beardstown, W. of channel	88	Feb. 5	"	2.0	Middle	3.3
Phelps Ditch	92	Feb. 5	Covered with heavy ice. Much snow water coming in	—	Bottom	2.0
				—	Top	7.1
					Snow water on top of ice.	10.2
Treadway Lake	93	Feb. 6	Some open water in the channel	—	Bottom	5.2
				—	Bottom	5.1
Coleman Lake	93	Feb. 6	A little open water	—	Bottom	5.1
Pekin, mid-channel	153	Feb. 6	Channel open. Shore ice	2.0	Bottom	3.3
				2.0	Top	3.4
Peoria Narrows, mid-channel	166	Feb. 6	Channel open except in the wide waters of Peoria Lake	1.5	Bottom	2.8
				1.5	Top	3.0
				2.0	Bottom	2.9
				2.0	Top	3.1
Henry, mid-channel	196	Feb. 7	Channel half open	2.0	Bottom	4.7
				2.4	Top	4.7
Chillicothe, mid-channel	180	Feb. 7	Channel open	2.0	Bottom	5.5
				2.0	Top	5.6
Brockschmidt's Swale	92	Feb. 9	Much open water	1.0	Bottom	8.0
Treadway Lake near boat-landing	92	Feb. 9	"	—	Bottom	7.9
				—	Bottom	8.2

TABLE I. (*Concluded*)

Location	Miles above Grafton	Date 1925	Ice conditions	Water temp. C.	Sample taken from	Dissolved oxygen parts per million
Browning, mid-channel	97	Feb. 10	No ice	1.5	Bottom	5.8
				1.5	Top	5.7
Browning, W. shore	97	Feb. 10	"	3.0	Middle	5.8
Coleman Lake, E. shore	93	Feb. 11	Some new ice	—	Middle	6.4
Beardstown, mid-channel	88	Feb. 11	No ice	—	Top	6.6
Spring Bay near grain elevator	174	Feb. 17	Some new ice	—	Bottom	8.7
Peoria Narrows, mid-channel	166	Feb. 17	No ice	—	Top	7.6
Dickinson's Slough	175	Feb. 17	Some shore ice	—	Bottom	6.8
				—	Bottom	5.9
Lower Peoria Lake, E. shore	164	Feb. 18	West half of lake open	—	Bottom	4.1
				—	Bottom	3.9
Peoria Narrows, mid-channel	166	Feb. 18	Lakes half open	—	Top	7.2
Lower Peoria Lake, E. shore	164	Feb. 19	Lakes open. Some shore ice	—	Bottom	7.4
				—	Bottom	6.9
				—	Bottom	5.7
Water-works Point, mid-channel	164	Feb. 19	"	—	Bottom	8.9
Beardstown, mid-channel	88	Feb. 21	No ice	3.5	Middle	7.9
				2.4	Top	7.6
Brockschmidt's Swale	92	Feb. 24	"	4.0	Bottom	8.9
				5.5	Bottom	9.3
Meredosia Bay at the head	78	Feb. 26	"	—	Middle	9.1
				—	Middle	10.7
Meredosia, mid-channel	71	Feb. 26	"	—	Top	9.0
				—	Top	10.3
Vette Swale	93	Feb. 27	"	—	Bottom	8.9
				—	Bottom	9.0

A sample taken February 17 at Peoria Narrows with some new shore ice present showed 7.6 parts per million of dissolved oxygen, and a sample on February 18 showed 7.2 at the same place, with no change in temperature. On February 19 at Water-works Point, where there was still some shore ice, samples showed 8.9 parts per million of dissolved oxygen. For the remainder of February the dissolved oxygen figures ranged from 8 to 10 parts per million in the vicinity of Beardstown and Meredosia, with no ice and with the water temperature about 4° C.

From late autumn until late spring the water of the Illinois River is cold enough to slow down the oxygen consumption of the organisms that utilize the sewage and other organic matter in the river to a point where the rate of aeration balances or exceeds the rate of oxygen consumption. Under these conditions the amount of oxygen present is sufficient for the ordinary river animals. If, however, aeration is stopped by the freezing over of the river the dissolved oxygen is gradually exhausted until it becomes so low in Upper Peoria Lake that fish show signs of distress. When this condition is established, it does not change until the ice goes out or until it is diluted with a large amount of water highly charged with oxygen. When the ice goes out of a small fraction of the channel there is a marked increase in the amount of oxygen dissolved in the water, and in about a week the normal cold water concentration of dissolved oxygen is established.

The Effect of Low Dissolved Oxygen Concentrations on the Fishes of the Illinois River

Fishes, like all other living things, require a more or less constant supply of oxygen to maintain the activities of life, but the minimal amount may vary greatly for the different forms of life. A striking example of this is the problem in hand. The minute organisms which feed on sewage and other organic matter can live and consume oxygen in concentration too small to support the life of fishes. Some of them, indeed, can live in a total absence of dissolved oxygen, since they are able to derive oxygen from complex organic compounds.

A fact of fundamental importance to the existence of fishes is their ability to avoid oxygen concentrations that would be fatal to them. When low dissolved oxygen concentration obtains in a body of water, such as the Illinois River, the fishes retreat into backwater lakes, spring holes, mouths of tributaries, and other places where stagnation has not developed.

A case of this kind recently occurred near the town of Spring Bay on the east shore of upper Peoria Lake, where there is a lagoon fed by springs. At rather low stages of the river this lagoon, which has an area of about two acres, is filled with clear, well-aerated water, warm enough to prevent freezing. Some time after the river was completely frozen over in January, 1925, the fishes began to crowd into this spring hole, and several carloads of carp and buffalo were taken here during the last two weeks of January. A rise in the stage of the river largely diluted this better water with the oxygen-deficient river water, and large numbers of minnows, large-mouth black bass fingerlings, crappies, sunfishes, etcetera, died; and the carp became much distressed and swam at the surface with their heads out of the water. Part of the ice then went out of the channel, the dissolved oxygen in the river water increased, and the fishes no longer were attracted to this place. The unusually large numbers of gulls that frequented the river at that time may indicate an unusually large number of dead fishes; but, with the above exception, no dead fishes were seen by the writer except where they had been confined in live-boxes, traps, and nets, and could not escape from the oxygen-deficient water.

Those animals which are more sedentary in their habits and can not so readily avoid oxygen-deficient water suffer more severely than the fishes. After the recent prolonged period of ice, large numbers of dead snails were washed up on the east shore of lower Peoria Lake. Fishermen in the vicinity of Meredosia and Beardstown have in recent years remarked the growing scarcity of air-breathing animals that hibernate on the bottom of the river, such as bull-frogs, snapping turtles, and soft-shelled turtles. Some of the turtles, however, such as the painted turtle, the ridge-back turtle, and the terrapin, do not bury themselves in the mud and hibernate, but remain active, as shown by the fact that they are caught in hoop-nets and traps throughout the winter. These latter species of turtles are much more plentiful in the lower Illinois River than the hibernating species. In cold water, frogs and turtles utilize the oxygen in the water and can dispense with the use of their lungs. If they remain active they select the better water the same as the fish; but if they bury themselves in the mud and become dormant, it may be that they die there from deficiency of oxygen during times of stagnation.

In the attempt to determine what dissolved oxygen concentrations the different fishes avoid and what concentrations are fatal to them, dissolved oxygen determinations were made where fish were being taken, where they customarily had been taken but were absent at the time, and where fish were dying. The procedure followed was to accompany a fisherman who was raising hoop-nets and take dissolved oxygen samples at the nets. This was done at nets which had been fishing one, two, or at most three days, and, when convenient, both when the nets were set and when they were raised. The samples were usually taken near the bottom because that is where the fish spend most of their time. One advantage of hoop-nets is that they can be used in all kinds of situations where the hauling of seines is often impossible. For the purpose of ascertaining the relations of fish life to dissolved oxygen, hoop-nets have the further advantage, that they fish a very restricted area. The amount of fish taken by them depends on conditions which cause the fish to move about, such as high winds, changes in the stage of water, changes in the quality of the water, and changes in temperature. What may be considered a disadvantage of hoop-nets is their selectiveness. Sluggish fish are not caught as often as active fish. Carp avoid small-mesh nets and traps, but they are readily taken in large-mesh nets. Channel cat and bullheads seem to go most readily into small-mesh nets and basket traps, probably because, being largely nocturnal and hiding during the day, they go into the nets for concealment.

Table II gives the winter data showing the relation of fishes to different conditions of ice and dissolved oxygen. It seems quite certain that dissolved oxygen concentrations between zero and two parts per million will kill all kinds of fishes. Carp and buffalo have been found living in water showing as low as 2.5 parts per million. As a rule, a variety of fishes were found only when they were four or more parts per million, and the greatest variety of fishes was taken when there were nine parts per million. This catch was made on February 26-27 in Vette Swale when at least twenty-two and perhaps as many as twenty-six species of the larger fishes were taken in nine 2½-inch mesh four-foot hoop-nets.

It was noticed a number of times that carp and buffalo taken from oxygen-deficient water were very light in color and sluggish in their movements, while the same kinds of fishes taken from well-aerated water were quite darkly pigmented and very active when disturbed.

Mention was made by fishermen, from time to time, at several points on the Illinois River, of the inferior value of certain fish because they were "gassy"—their expression for a taste and smell of the flesh of the fish, like the smell of coal gas. Others have described it as like the taste of kerosene or of tar; but to the writer it seems more than anything else like the smell of the putrifying mud on the bottom of the river, which is very like that of coal gas. This taste is often so pronounced as to make the fish very disagreeable as food. "Gassy" fish are definitely associated with periods of prolonged ice on the river, mortality in nets and traps, and other indications of a scanty supply of dissolved oxygen. The species which most commonly have this taste are carp, buffalo, channel cat, and bullheads, and these are the species which are most often found living in water with a low oxygen concentration. If these fishes are kept in well-aerated water for a few days, they lose this "gassy" taste.

During the winter, except when the river is frozen over, fishes do not suffer directly from lack of dissolved oxygen. From November to May, in open water, the rate of aeration exceeds the rate of oxygen consumption, so that there is usually a sufficiency of dissolved oxygen.

In midsummer, down as far as Peoria and sometimes below, except during high water, lack of dissolved oxygen excludes fishes from large feeding grounds and destroys large amounts of fish food. For example, Mr. Richardson observed a heavy mortality of snails in Peoria Lake in August, 1917. As increase in temperature accelerates the life processes of fishes, lack of dissolved oxygen can not be endured in warm water as long as in cold.

TABLE II. THE RELATION OF ICE, DISSOLVED OXYGEN, AND FISH LIFE IN THE ILLINOIS RIVER AND RELATED WATERS, 1925

Location	Date 1925	Ice conditions	Dissolved oxygen parts per million	Notes on fish life, etc.
Clear Lake, at Haven's Landing	Feb. 2	Completely covered with heavy ice	1.7 Bottom	No fish here now. Fish caught in hoop-nets die. Carp, buffalo, yellow bass, bullheads and channel cat as well as some sunfish and crappies are ordinarily taken here.
Mud Lake, in the middle	Feb. 2	"	0.4 Bottom 1.2 Top	No fish here now. Carp, buffalo, yellow bass, bullheads, channel cat, crappies and sunfish ordinarily taken here.
Mud Lake, E. shore	Feb. 2	"	1.0 Middle	Ten days ago a river seine was hauled here under the ice and 300 lbs. of buffalo were caught. A few gizzard shad and gars were also taken.
Quiver Creek	Feb. 3	All open water except a little shore ice	11.4 Bottom 11.1 Top	See column A. Fishes taken in ten 2-inch mesh, 4-foot hoop-nets in one day.
Quiver Lake near the mouth of Quiver Creek	Feb. 3	Open water about the mouth of Quiver Creek	5.7 Bottom	Hoop-nets in this open water are catching many carp, buffalo, and "fine fish."
Quiver Lake, in the middle	Feb. 3	Covered with heavy ice	2.3 Bottom	A seine haul last week caught 800 lbs. of carp and buffalo that were very pale and sluggish. Strings of bullheads are being taken with the hands at the edge of the ice along the shore.
Coleman Lake, in the middle	Feb. 4	Covered with heavy ice	5.0 Bottom 5.4 Top	Samples taken at some hoop-nets set on Feb. 2.
Treadway Lake, E. shore	Feb. 4	"	5.0 Bottom	"
Treadway Lake, in the middle	Feb. 4	"	5.4 Bottom	"
Phelps Ditch	Feb. 4	"	1.5 Bottom	Fish caught in hoop-nets in this ditch smother quickly. Gar, crappies, sunfish, black bass, yellow bass, bullheads, channel cat, carp, buffalo, and dogfish commonly taken here.

TABLE II. (*Continued*)

Location	Date 1925	Ice conditions	Dissolved oxygen parts per million	Notes on fish life, etc.
Phelps Ditch	Feb. 5	Completely covered with ice. Much snow water coming in	2.0 Bottom 7.1 Top	
Treadway Lake	Feb. 6	Some open water in the channel	5.2 Bottom 5.1 Bottom	See column B. Fishes taken in twenty-nine 2½-inch mesh, 4-foot hoop-nets in four days.
Brockschmidt's Swale	Feb. 6	Some open water		See column C. Fishes taken in three 2½-inch mesh, 4-foot hoop-nets in one day.
Coleman Lake	Feb. 6	A little open water	5.1 Bottom	See Column D. Fishes taken in twenty-five 2½-inch mesh, 4-foot hoop-nets in three days.
Brockschmidt's Swale	Feb. 9	Much open water	8.0 Bottom	Heavy rain yesterday; river rose a foot. See column E. Fishes taken in three 2½-inch mesh, 4-foot hoop-nets in three days.
Treadway Lake near boat landing	Feb. 9	"	7.9 Bottom 8.2 Bottom	Heavy rain yesterday; river rose a foot. See column F. Fishes taken in seven 2½-inch mesh, 4-foot hoop-nets in two days.
Dickinson's Slough	Feb. 17	Some shore ice	6.8 Bottom	See column G. Fishes taken in one 1½-inch mesh, 2-foot hoop-net in two days.
Dickinson's Slough	Feb. 17	"	5.9 Bottom	See column H. Fishes taken in one 2-inch mesh, 4-foot hoop-net in two days.
Lower Peoria Lake, E. shore	Feb. 18	West half of lake open	4.1 Bottom 3.9 Bottom	See column I. Fishes taken in five 1½-inch mesh, 3-foot hoop-nets in two days.
Lower Peoria Lake, E. shore	Feb. 19	Lakes open. Some shore ice	7.4 Bottom 6.9 Bottom 5.7 Bottom	See column J. Fishes taken in nine 1½-inch mesh, 3-foot hoop-nets in one to three days.
Brockschmidt's Swale	Feb. 24	No ice	8.9 Bottom 9.3 Bottom	See column K. Fishes taken in eight 2½-inch mesh, 4-foot hoop-nets in one day.
Coleman Lake	Feb. 24	"		See column L. Fishes taken in two 2½-inch mesh, 4-foot hoop-nets in one day.
Vette Swale	Feb. 27	"	8.9 Bottom 9.0 Bottom	See column M. Fishes taken in nine 2½-inch mesh, 4-foot hoop-nets in two days. The river is rather high and these nets were set among brush. A high wind blew all day yesterday.

TABLE II. (*Concluded*)

Kinds and Numbers of Fishes Taken

Name	A	B	C	D	E	F	G	H	I	J	K	L	M	Total
Carp	137	173	3	68	12	42		9	39	81	14	4	64	646
Big-mouth buffalo	27	20	2	11		1			7	22		1	11	102
Mongrel buffalo		1		5		1			5	3			4	19
Small-mouth buffalo		19	1	21	14	1			3	3	11	2	17	92
River carp	55	10		5		2			5	14	2		15	108
Hogsucker		1											1	2
Common sucker						2			1	1			1	5
Spotted sucker						1							1	2
Chub-sucker				1						1				2
Red-horse		1		3							2		2	8
Short-nosed gar	2		1	2			1		11	15			3	35
Long-nosed gar				1										1
Dogfish				2									2	4
Bullheads	4	13		26			11		8	34			15	111
Channel cat	32	11		1					1	1	2		1	49
Sheepshead	2										2		5	9
Yellow bass	44												4	48
Large-mouth black bass	1			3									12	16
White crappie		2		21									14	37
Black crappie				11					1				6	18
Blue-gill		1		15			2						9	27
Warmouth bass							1						2	3
Green sunfish							1		3	3			3	10
Eel													1	1
Total	304	252	7	196	26	50	16	9	84	178	33	7	193	1355

Summary of Table II

Column	No. of nets	Width of mouth	Mesh inches	Fishes per net per day
A	10	4	2	30.4
M	9	4	2½	10.7
I	5	3	1½	8.4
G	1	2	1½	8.0
J	9	3	1½	6.6
H	1	4	2	4.5
K	8	4	2½	4.1
F	7	4	2½	3.6
L	3	4	2½	3.5
E	3	4	2½	2.9
D	25	4	2½	2.6
C	2	4	2½	2.5
B	29	4	2½	2.2

Observations made at Peoria Narrows in the summer of 1923 showed that fishes died over night in water having less than two parts of oxygen per million. Dogfish seemed to be most sensitive to low oxygen concentrations, for individuals of that species were often found dead when all other species remained alive in the same hoop-net. Carp seemed to be the most resistant, being often caught farther out in the channel than other species, in nets where the water was deficient in oxygen. Gars were more abundant than any other species in water with little or no oxygen, probably because of their habit of breathing at the surface.

The Effect of Dissolved Oxygen Concentration on the Fish Yield of the Illinois River

Table III gives the fish yields for the different sections of the Illinois River in representative years covering almost two decades. The peak of fish production was reached in 1908, when the Illinois River produced over 19 million pounds, according to the Illinois Fish Commission report, and almost 24 million pounds, according to the U. S.

Bureau of Fisheries. The factors entering into the increase of the fish yield were principally:

(1) The introduction of the German carp.

(2) The increase in fishing operations.

(3) The increase in the area of the river due to the addition of water from Lake Michigan.

(4) The increase in the food supply resulting from the sewage.

TABLE III. COMPARISON OF THE FISH YIELDS OF THE DIFFERENT SECTIONS OF THE ILLINOIS RIVER

Year	Authority	La Salle-Chillicothe	Peoria-Browning	Beardstown-Grafton	Total
		Pounds	Pounds	Pounds	Pounds
1896	Ill. Fishermen's Ass'n	735,500	3,854,281	2,643,281	7,232,811
1897	"	1,904,095	5,579,963	2,412,650	9,896,708
1899	"	2,040,045	6,025,671	3,541,800	11,607,516
1900	"	1,803,600	5.178,140	4,542,440	11,524,180
1907	Ill. Fish Commission	1,455,000	9,900,000	3,384,000	14,739,000
1908	"	1,722,000	13,600,000	3,948,000	19.270,000
1921	Bureau of Fisheries	542,985	1,989,249	1,474,233	4,006,467
1922	"	1,055,184	5,856,778	3,694,710	10,606,672

Since 1908 there has been a marked decrease. A census taken by the U. S. Bureau of Fisheries in 1921, a poor fishing year, showed 4 million pounds; and in 1922, a favorable year for fishing, the census showed 10½ million pounds. The factors entering into this decrease are:

(1) The reclamation of the bottomlands and lakes along the middle and lower sections of the river.

(2) The exclusion of fishes from large areas of the upper and middle river during a large part of the year, due to conditions produced by an excess of sewage.

(3) Occasional periods of extraordinary pollution which wipe out whole populations of organisms that serve as fish food and which destroy large numbers of the fishes themselves in places where they can not retreat into better water.

Messrs. Alvord and Burdick, in their report on "The Illinois River and its Bottomlands" (1915), have shown that the fish yield is closely correlated with the water area. In the Beardstown-Grafton section of the river there has been no very marked change in the amount of fish taken. Here the factors making for increased yield have been offset largely by reclamation of the bottomlands. The greatest change took place in the Peoria-Browning section, where there was a marked increase in fish yield up to 1908 and an equally marked decrease after 1908. Here the reclamation of bottomlands, notably the Thompson's Lake district, took place several years later than in the lower section of the river. In the upper section (La Salle-Chillicothe), although considerably less land has been reclaimed, and the higher stage of the river has increased the area of water, the fish yield shown by the 1921 and 1922 figures is scarcely half its former value. This decrease has been brought about entirely by the conditions produced by an excess of sewage.. The most important effect of an excess of sewage is the reduction of dissolved oxygen to a point where fish life is excluded from immense areas of water.