MAN'S EFFECT ON THE FISH AND WILDLIFE OF THE ILLINOIS RIVER

Illinois
Natural History Survey
Biological Notes No. 57
Urbana, Illinois
June, 1966

Harlow B. Mills, William C. Starrett, and Frank C. Bellrose

TE OF ILLINOIS · DEPARTMENT OF REGISTRATION AND EDUCATION · NATURAL HISTORY SURVEY DIVISION

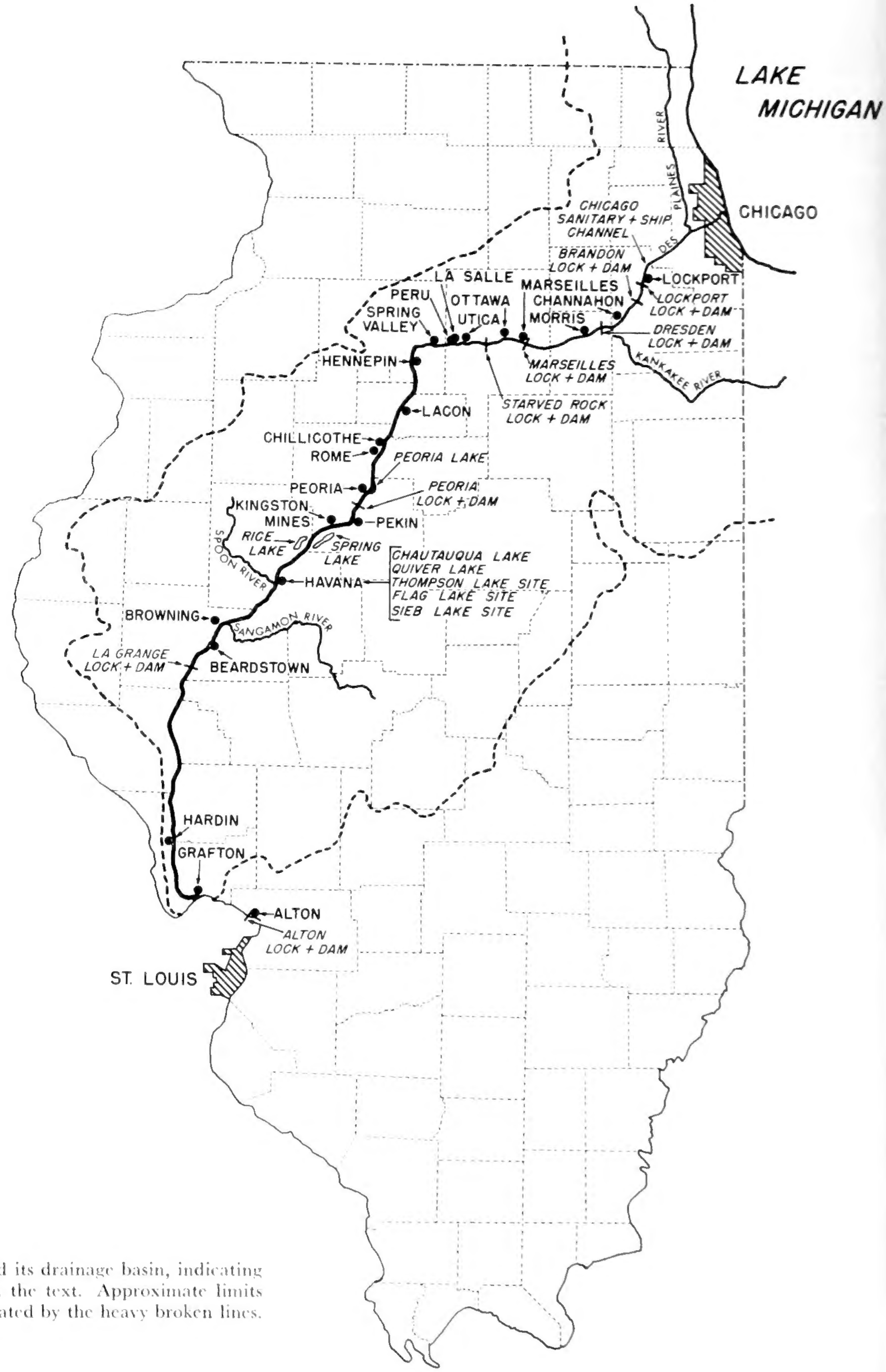

Fig. 1. — Illinois River and its drainage basin, indicating the main features discussed in the text. Approximate limits of the drainage basin are indicated by the heavy broken lines.

COVER PHOTO: Natural History Survey crew taking dissolved oxygen readings with a galvanic oxygen analyzer. Photo by George W. Bennett.

MAN'S EFFECT ON THE FISH AND WILDLIFE OF THE ILLINOIS RIVER

Harlow B. Mills, William C. Starrett, and Frank C. Bellrose

THIS IS A DOCUMENTED REPORT on changes in the Illinois River, primarily in the past 75 years, with emphasis on the biological modifications which have occurred and are occurring as a result of man's activities.

The Illinois River has been called the "most studied" river in the world. Certainly there is a great heritage of biological information obtained from this stream. We have drawn freely on the observations of Kofoid, Forbes, Richardson, and many others, and have included more modern observations which we and some others have been in a position to make.

The river has not shown steady changes from year to year. Rather, many of them have occurred with great rapidity and some have not been permanent. For example, the acreage of water, which went up greatly due to diversion from Lake Michigan in 1900, was reduced almost to its pre-1900 surface by 1913. This reduction was due to the development of levee districts, which claimed and drained large areas of the floodplain, and subsequently to decreased lake water diversion in the 1930's.

Most of the observations in this publication relate to the main stream and its lateral bottomland lakes, but these areas are only what the basin makes them.

THE RIVER AND ITS BASIN

The basin of the Illinois River and its tributaries is comprised of 32,081 square miles, which is more than half the area of the state of Illinois (Barrows 1910:1). The name "Illinois" is applied to that part of the drainage below the confluence of the Kankakee and Des Plaines rivers southwest of Chicago, the Kankakee rising in Indiana and the Des Plaines in Wisconsin. The group of glacial lakes in the northeast part of the state drains into the Illinois River through the Fox River. The Illinois River is 272.4 miles long, and the entire waterway from Lake Michigan to the mouth of the river is 327 miles long. The river flows nearly west to Hennepin where it turns abruptly southwest, arriving at the Mississippi near Grafton, above St. Louis (Fig. 1). Thus, it traverses a large section of the state, and is affected by and affects the majority of the state's citizens.

Barrows (op. cit.) referred to the Illinois valley as the most conspicuous topographic feature of Illinois. He stated that, ". . . certain peculiarities of the lower Illinois render it unique among rivers, the region is one of particular interest. . . . The lower Illinois presents a second peculiarity in its remarkably gentle fall. . . . The average fall between Hennepin and Pekin, a distance of 55.8 miles, is 0.82 inch per mile. The Illinois is a river of relatively insignificant volume. Its natural low-water discharge is less than that of the Rock River and but a small fraction of that of the upper Mississippi and Ohio rivers. The nearly level channel and the small volume result in a very sluggish river, which has been described as a stream that 'more nearly resembles the Great Lakes than an ordinary river,' and again as one that 'partakes more of the nature of an estuary than of a river.' It is wholly unequal to the task of washing forward the sediment delivered by its headwaters and its numerous tributaries. . . . The average fall of the lower Illinois is less than that of the Mississippi below the mouth of the Illinois. This is the reverse of the normal relation between tributaries and their main streams."

This unique condition for a river has been brought about by the present stream flowing through much of its length in a valley developed in the late Pleistocene epoch. During that time a much larger water volume produced by receding glaciers fashioned the present physiography.

It might be well here to describe the Illinois River's bottomland lakes (lateral levee lakes). The river, flowing in its unusually wide valley and carrying a silt load, drops more of this silt at the quieter edges than in the more rapid stream center. This builds up low natural levees along its shores. Overflow of the river at high water leaves large impoundments behind these levees as the water recedes. Usually these impoundments are shallowly connected with the river at their upper and lower ends.

Man's treatment of the river has tended to aggravate its natural tendency to deposit sediment. The building of several dams across the river for navigation purposes has tended to slow the water even more. Also, the greater tillage of the agricultural upland has increased the amount of silt that is carried into the quiet mainstream waters.

The Illinois River was the highway for explorers of the area, and early settlements were made on its shores. Many early writers were impressed by it.

Following an ascent of the Illinois River in 1673, Marquette (Kenton 1925) wrote as follows: "We have seen nothing like this river that we enter, as regards to its fertility of soil, its prairies and woods; its cattle, elk, deer, wildcats, bustards, swans, ducks, parroquets, and

This paper is published by authority of the State of Illinois, IRS Ch. 127, Par. 58.12. It is a contribution from the Sections of Aquatic Biology and Wildlife Research of the Illinois Natural History Survey. Dr. Harlow B. Mills is Chief of the Survey. Dr. William C. Starrett is an Aquatic Biologist, and Frank C. Bellrose is a Wildlife Specialist.

even beaver. There are many small lakes and rivers. That on which we sailed is wide, deep, and still, for 65 leagues."

Thomas Jefferson (1787:13) wrote "The Illinois is a fine river, clear, gentle, and without rapids; insomuch that it is navigable for batteaux to its source." In 1838 Captain Howard Stansbury described the valley as "one to five miles wide, deeply overflowed in every freshet, filled with bayous, ponds, and swamps, and infested with wild beasts . . ." (Mulvihill and Cornish 1929:27).

To come down to the beginning of the present century, Kofoid (1903:151–155) described the river and its bottomland lakes at a high water stage in May, as it was just above Havana: "As we leave the sandy shore of Quiver we traverse the clear, cold, and spring-fed water along the eastern bank with its rapidly growing carpet of *Ceratophyllum* [coontail], and in a few rods note the increasing turbidity, rising temperature, and richer plankton of the water which has moved down from the more or less open and slightly submerged bottom to the north. . . . The water [of the river] also appears much more turbid by reason of silt and plankton, and no trace of vegetation is to be seen save occasional masses of floating *Ceratophyllum* or isolated plants of *Lemna*, *Wolffia*, or *Spirodela* [duckweeds]. . . . As we plunge into the willow thicket on the western shore we have to pick our way through the accumulated drift lodged in the shoals or caught by the trunks of the trees or the submerged underbrush. . . . From this dark labyrinth we emerge to the muddy but quiet waters of Seeb's Lake with its treacherous bottom of soft black ooze. We next enter a wider stretch of more open territory with scattered willows and maples and a rank growth of semi-aquatic vegetation, principally *Polygonums* [smartweeds]. The water is clearer and of a brownish tinge (from the diatoms), while mats of algae adhere to the leaves and stems of the emerging plants. A flock of startled water-fowl leave their feeding grounds as we pass into the wide expanse of Flag Lake. We push our way through lily pads and beds of lotus, past the submerged domes of muskrat houses built of last year's rushes, and thread our way, through devious channels, among the fresh green flags and rushes [probably river bulrush, *Scirpus fluviatilis*] just emerging from the water. Open patches of water here and there mark the areas occupied by the 'moss' or *Ceratophyllum*, as yet at some depth below the surface. The *Lemnaceae* [duckweeds] are everywhere lodged in mats and windrows, and amidst their green, one occasionally catches sight of a bright cluster of *Azolla* [mosquito fern]. The water is clear and brownish save where our movements stir the treacherous and mobile bottom. . . . Thompson's Lake, the largest expanse of water in the neighborhood, is wont to be rough in windy weather, but if the day be still we can see the rich aquatic vegetation which fringes its margin and lies in scattered masses toward its southern end. Its waters seem somewhat turbid, but more from plankton than from silt, though the deep soft mud which forms much of its bottom is easily stirred. . . . The new vegetation is already springing from the decaying and matted stems of the preceding summer."

Later in the season when the water was at a low stage, Kofoid (op. cit.:155) noted, "The backwaters have been reduced to the lakes, sloughs, bayous, and marshes which abound everywhere in the bottom-lands." Flag Lake had lost its connection to the river and was a "sea of rushes." Thompson Lake still maintained a connection of sorts with the Illinois through a slough, and was choked with vegetation at its southern end. Quiver Lake was completely choked with aquatics except for one narrow channel where clear, open water prevailed.

The present-day condition is well described by Starrett and Fritz (1965:88): "Today Quiver Lake is devoid of aquatic plants. The formerly deep basin of the lake has been filled in with 4- to 8-foot deposits of silt. Turbid water at depths of over 3 feet and a soft, flocculent bottom prevent the establishment of aquatic plants in the lake. Conditions in Quiver Lake are duplicated in many of the other floodplain lakes of the Illinois River; that is, in the past 35 years siltation has greatly changed the ecology of these lakes."

HUMAN POPULATIONS AND ACTIVITIES

In the early days of exploration and settlement of Illinois the rivers were the arteries of travel, communication, and commerce. It was not until the era of railroads that the people of Illinois were in a great measure emancipated from the rivers.

Little concern was shown about changes in, or the changing of, the Illinois River for the first 250 years of its use by white people. Its character seemed to remain about the same, although the greatest flood ever recorded for the river was in the 1840's. Steamboats made their way far up its reaches in the 19th century. Cities sprang up along its shores and, near the headwaters, Chicago began its growth. Events happened rapidly from the last quarter of the 19th century to the present time.

To give a simple illustration of the development in the river's basin, the population of the counties which are all or in part drained by the Illinois River changed from about a half-million in 1850 to 1,629,738 in 1870. By 1964 this figure had risen to 8,537,900 of a total state population of 10,500,000.

Man has made several major changes in the river itself. On January 1, 1900, the Sanitary and Ship Canal was opened at Chicago, connecting the Des Plaines and Illinois rivers with Lake Michigan. The great quantities of water thus diverted flushed untreated domestic sewage and industrial wastes down the canal and into the Illinois River system. This directed these materials away from the lake, which the city used as a source for its water supply.

Forbes & Richardson (1919:140–141) reported an average rise of 2.8 feet at Havana as a result of this diversion, and between June and September the level rose an average of 3.6 feet above prediversion averages. This flooding had several effects on the river. It permanently inundated thousands of acres, ultimately killing bottomland forests. Where trees like the pin oak (*Quercus palustris*) and the pecan (*Carya illinoensis*) were involved, this meant a loss of food for mallards and wood ducks, but there was also a considerable increase in water surface which was beneficial to the fishery. Forbes and Richardson (op. cit.:141) commented that Thompson Lake increased in surface from 1,943 to 5,072 acres. As late as 1940, dead snags from this "drowned forest" were still in evidence, but time and man's later activities have erased most of the traces of the old lakes, sloughs, and bottomland forests which existed prior to the 1900 diversion.

These same authors (op. cit.:142) give a good account of the effects of this inundation: "This destruction of inshore and alongshore vegetation has been especially conspicuous in the broad belt of deadened trees and shrubs along the banks, especially in the middle course of the stream from Peoria southward. Other important effects are beginning to appear as these dead trees weaken and fall into the water of the stagnant lakes, fouling them, in the hottest weather, with the products of vegetable decay."

In 1848 the Illinois-Michigan Canal was opened, and in 1907 the Hennepin Canal connected the Illinois with the Mississippi. Drainage of bottomlands for agricultural purposes followed closely on the heels of the diversion from Lake Michigan. Actually drainage started in a small way prior to 1900 (Mulvihill and Cornish 1929:38), but most of the drainage enterprises were initiated between 1903 and 1920. The last levees were started between 1918 and 1921. Initially there were 400,000 acres subject to overflow between La Salle and Grafton. At the height of the drainage period there were 38 drainage districts and three private drainage areas aggregating 200,000 acres. Spring and Thompson Lakes, long known for their fisheries and their concentrations of waterfowl, were eliminated as were a host of smaller lakes and sloughs. How drainage and levees have changed the floodplain near Havana is illustrated by Fig. 2.

There has been some abandonment of drainage districts. Prior to 1920 the Partridge District, across from Chillicothe, failed, and after the flood of 1926 the Chautauqua Levee District near Havana and the Big Prairie Levee District near Beardstown were discontinued. These abandonments resulted in a return of 8,000 acres to fish and wildlife habitat.

Another human activity has conspicuously changed the river. Before 1900, low dams were built at Marseilles, Henry, Copperas Creek, La Grange, and Kampsville. Because they were low, their greatest effect on the stream was during periods of low water. During the 1930's, higher navigation dams were built at Dresden Heights (22 ft), Marseilles (24 ft), Starved Rock (19 ft), Peoria (11 ft), and La Grange (10 ft). Moreover, a navigation dam on the Mississippi at Alton raised water levels in the Illinois River as far north as Hardin.

Barge traffic on the river is now very heavy, and there is a consequent effect on the turbidity of the water in the main stream and adjacent waters.

Soil pollution has been present in Illinois River waters since the recession of the last ice sheet. However, the laying bare of the soil in agricultural operations has greatly increased the problem.

A study of Lake Decatur, on the Sangamon River, a tributary of the Illinois, showed that the rate of sedimentation was about 20 percent greater in the decade starting in 1936 than it was in the preceding 14.2 years (Brown, Stall, & DeTurk 1947). In one county above the impoundment row crops increased from 39 percent of the total area in 1924 to 64.5 percent in 1943. There is a probable cause-and-effect relationship here. This sedimentation is a serious matter to organisms that live in the water as well as to those that use it. Further, it displaces water. Where waters are stilled, the load of silt is dropped, and the water is replaced by soil.

In 1964, in the counties drained wholly or in part by the Illinois River 6,220,200 acres were planted to corn for grain which was valued at $530,288,900, and an additional 3,466,100 acres were planted to soybeans (Illinois Cooperative Crop Reporting Service 1965). Thus, in these counties 47 percent of the land surface in 1964 was in row crops which leave the soil vulnerable to erosion.

The streams that flow into the Illinois have a steeper gradient than does the Illinois in its central and lower reaches. Since the river is impounded and the gradient is low, it has difficulty carrying its silt load. Therefore a tremendous amount of this turbid burden is deposited in the remaining floodplain lakes when spring floodwaters top the low natural banks. An example of the seriousness of siltation is evident in the study made by Stall & Melsted (1951) of Lake Chautauqua. They found that in a 23.8-year period the sediment had reduced the storage capacity of this artificial lateral bottomland lake by 18.3 percent, nearly one fifth. Other bottomland lakes are steadily diminishing in size and depth as sediments continue to be deposited in spite of soil conservation measures.

The basic reason for the 1900 diversion of Lake Michigan water into the Illinois waterway was to dilute sewage and transport it away from Chicago. Since that time the treatment of sewage in the Chicago area has been greatly improved, but the rich effluent still affects the waters of the waterway below the city (Keup, Ingram, Geckler, & Horning 1965). Moreover, the other cities within the Illinois River basin have grown, and make their increasing demands on and contributions to the stream.

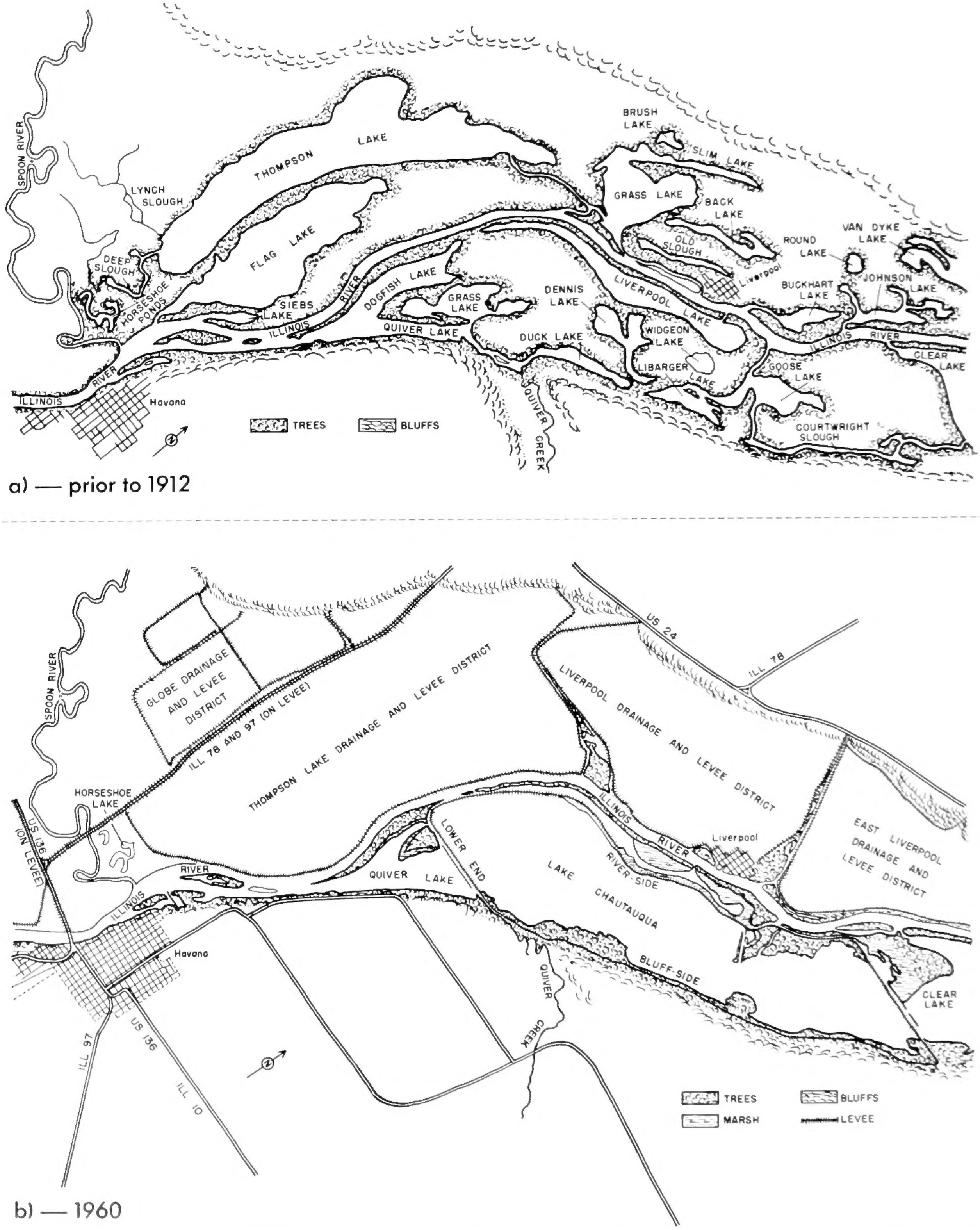

Fig. 2. — Illinois River bottom near Havana, Illinois, a) as it was prior to 1912, and b) as it was in 1960. (From Starrett & Fritz, 1965.)

Domestic sewage and industrial wastes are not the only source of organic pollution of our streams. With the development of larger and larger cities, the paving of more streets, parking areas, etc., the storm water runoff adds a considerable amount of organic material. A study by Weibel, Anderson, & Woodward (1964) of a sewered storm water runoff from a 27-acre, residential-light commercial area in Cincinnati, Ohio, disclosed that, assuming a secondary sewage treatment plant effluent at the population density and environmental conditions of this area, the oxygen demand of the storm water would equal about 60 percent of the oxygen demand of the sewage effluent on a yearly basis.

Man is contributing other things to the Illinois River. No one knows what all of these contributions are, in addition to those from industry and farming operations, or what they do to the environment. Usually these additions come to the attention of biologists only when there is a conspicuous deterioration of the biology of a stream.

Occasional accidents occur which affect the biology of the river, as, for example, when large quantities of ammonia fertilizer inadvertently escaped into it below Peoria in 1961.

With all that we are adding to the Illinois River, the known and the unknown, it is certain that the river is changing, and in some cases it is deteriorating rapidly insofar as it affects the well-being of the animals and plants that are dependent on it.

The following pages include a summary of some of our observations on this important stream. While we discuss some chemical and physical parameters to this problem, we are basically interested in them as they affect the fish and wildlife. It is probable that a greater future emphasis on the biology of streams will be a necessity in any intelligent water management program. Without in any way detracting from the importance of other fields of specialization, we believe that water biology stands at the center of any water quality consideration. In the words of Hynes (1964), "Pollution is, after all, primarily a biological phenomenon, as the things we need to know about water are almost all concerned with living organisms. Can we or our animals drink it? Will it be a good medium for brewer's yeasts? Is it likely to carry disease? Will it smell nasty as the result of biological degradation of organic matter? Can fish live in it?"

TURBIDITY

As mentioned previously, the Illinois River was at one time characterized as being clear. It has always carried some silt load, of course, but prior to human settlement of the basin this must surely have been a nominal one, and doubtless was most obvious during periods of high water. When the white settlers established the intense agrarian culture in the area, their plows and axes began a change in the river which still goes on. Kofoid (1903:179) discussed the matter of clarity as it was in 1896. He measured clarity by submerging a white plate of semiporcelain. The depth at which this plate disappeared from view was measured in centimeters.

"As might be expected in the river environment," he stated, "when floods occur the turbidity is often extreme, and is exceedingly variable according to the locality and the river levels. The extreme range of our records extends from 1.3 cm. [½ inch], in a Spoon River flood, to 260 cm. [8½ feet], in Quiver Lake, under the ice.

"In the [Illinois] river the great majority, about two thirds, of the records lie between 20 and 50 cm. [8–20 inches], while the extreme range is from 2 cm. [¾ inch], in the flood of May 1897, to 115 cm. [45 inches], in the declining waters of July, 1896." The range for two-thirds of his readings would be roughly estimated to equal 25–103 turbidity units (Jackson 1954:39).

Recent turbidity measurements have revealed how much greater the silt load is in the waters of the river than it was about 70 years ago. In 1963 and 1964, during periods of minimum flow when the silt load would be lowest, the turbidity was determined to be from 79 to 220 units in the La Grange Pool. Thus at this low-river stage, the modern measurements were at the lowest reading three times those of Kofoid's and at the highest reading over twice the 1896 figure. We have already discussed in general terms what this silt load is doing to water impoundments, and its relationship to modern agriculture. The lower and middle stretches of the river tend to be kept in a more turbid condition because of the movement of tow boats up and down the main stream (Starrett, unpublished). The increased turbidity of the Illinois River has come from the greater exposure of the soil to precipitation and resulting erosion, as discussed in the previous section, and from the hastening of the flow of the muddy waters into the stream. Great marshes, for example, used to impede the movement of rainfall to the river, but these marshes are largely gone now.

That the silt load in the lower river tends to be greater than in the upper stretches is indicated in the following tabulation which lists the turbidity units by navigation pools, beginning with the Alton Pool at the river's mouth and ending with the Dresden Pool in the Des Plaines River just below Chicago.

Navigation Pool	*Range in Turbidity Units*
Alton	71–320
La Grange	79–220
Peoria	15–140
Starved Rock	15–52
Marseilles	15–28
Dresden	15–27

These readings were made during the periods of minimum flow in the fall months of 1963 and 1964. During periods of high water all of these readings would, of course, be much greater; as high as 2,000 turbidity units have been noted by the Illinois Sanitary Water Board in the lower river during flood conditions.

Turbidity in parts of Peoria Lake is sometimes increased by large populations of minute floating plants known as phytoplankton, but in general the river's lack of clarity is due to suspended silt. Turbidity probably affects the procurement of food by sight-feeding fish (Starrett & Fritz 1965). It also affects production of plankton, and the well-being of various larger forms of aquatic plant and animal life (Ellis 1936).

DISSOLVED OXYGEN

Oxygen dissolves in water according to certain physical laws, and aquatic life has evolved to live and respire within the normal limits of this solution. Suffocation can take place if waters carry pollutants which will oxidize and remove this gas faster than it can be replaced. This makes too great a demand on the available oxygen, and fish, as well as other forms of aquatic life, will die.

The requirements for oxygen on the part of different aquatic species are not the same. Trout, for example, require more dissolved oxygen than do carp or goldfish. It appears from Ellis's studies (1937:372–373) that 5 parts per million (ppm) of dissolved oxygen is the lower limit for maintaining a desirable fish fauna in a river. Tarzwell (1958:19) believed that ". . . for a well-rounded warm water fish population, dissolved oxygen concentrations must not be below 5 p.p.m. for more than 8 hours of any 24-hour period and at no time should they be below 3 p.p.m." During the winter months on the Illinois River, Thompson (1925:431) noted that carp and buffalo were found in water having as little as 2.5 ppm of oxygen, but a variety of fish was found where there were 4 ppm, or more, and the greatest variety was found where there were 9 ppm. We also have found fish living in water with below 3 ppm of oxygen; however, we believe that prolonged low oxygen conditions are having a drastic effect on aquatic organisms in the river.

Continuous low oxygen determinations indicate that pollutants carried by the stream have a high biological and chemical demand on the oxygen supply and that the stream is in poor condition for fish life. Because the quantity of dissolved oxygen in the Illinois River water becomes an important limiting factor and has a strong relationship to the health of the organisms living in that water, it is important that we briefly review this factor. That low dissolved oxygen is a present as well as a past problem is indicated by the readings presented in Table 1.

Prior to 1800 the entire Illinois River system without doubt carried enough oxygen to support a well-diversified, healthy, fish population. Possibly a turning point occurred when the flow of the Illinois and Michigan Canal was reversed and began to bring sewage from Chicago to a point in the river at La Salle in 1871. The Peoria-Pekin area also began to develop along the middle stretch of the river. Sewage and industrial wastes coming into the river were untreated.

Kofoid (1903:199) estimated that the Illinois River received the untreated waste from a population of 1,032,229 people in 1890. There were no statistics as to the gallonage that this represented, but considering the pumpage into the water systems of the cities as an approximation of the sewage flow, he calculated that in 1897 the flow was 540,529,061 gallons per day. Kofoid stated (loc. cit.:230) that before the Sanitary and Ship Canal was opened in 1900 the nitrogenous material in the Chicago sewage was in the process of rapid oxidation in the upper reaches of the Illinois and Michigan Canal near Lockport, and that the process was largely completed by the time the canal water reached the Illinois River. He also said that in the summer months the wastes from Peoria were well decayed before reaching Havana, although in the winter the sewage was not so well oxidized.

As mentioned earlier, the opening of the Sanitary and Ship Canal in 1900 brought into the Illinois great quantities of sewage-laden lake water. Forbes & Richardson (1919:139) mentioned that in 1913 the flow of the Sanitary and Ship Canal amounted to 85.7 percent of the flow of the original river at Peoria.

By 1911 the upper part of the river was heavily polluted. Forbes (1911:5–6) stated: "Immediately below the mouth of the canal we have in the Des Plaines a mingling of these waters, and the Illinois River itself, below the junction of the Des Plaines and the Kankakee, the septic contributions of the former stream are largely diluted by the comparatively clean waters of the latter. Nevertheless, we had in July and August what may be called septic conditions for twenty-six miles of the course of the Illinois from its origin to the Marseilles dam. At Morris, which is on the middle part of this section, the water, July 15, was grayish and sloppy, with foul, privy odors distinguishable in hot weather. . . . Putrescent masses of soft, grayish or blackish, slimy matter, loosely held together by threads of fungi and densely covered with bell animalcules, were floating down the stream; and chunks of this material, from the size of a walnut to that of a milk pan, occasionally rose to the surface, evidently borne up by the gasses developing beneath them." He found that at that time the dissolved oxygen at Morris was only 9.8 percent of saturation. Sixteen miles below Morris, at Marseilles, the oxygen was only 7.5 percent of saturation. However, in the unpolluted Kankakee River 9 miles above Morris the dissolved oxygen was 112 percent of saturation.

The oxygen determinations given in Table 1 show how polluted the Illinois River was in 1911 and 1912 from Morris to Peoria.

Conditions became even worse during and immediately following World War I. Purdy (1930:2), who

Table 1.—Summary of minimum dissolved oxygen determinations near surface in channel of the Illinois and Des Plaines rivers during summer months of 1911, 1912, 1922, 1923, 1925, 1926, 1928, 1950, 1964, and 1965.

Nearest Town	Dissolved Oxygen in Parts per Million									
	1911[a]	1912[a]	1922[b]	1923[c]	1925[d]	1926[d]	1928[d]	1950[e]	1964[f]	1965[f]
Lockport	...	...	0.01	...	...	...	...	0.3	...	...
Channahon	...	...	0.2	...	...	...	...	1.2		1.6
Morris	0.9	...	0.2	...	...	...	0.6	...	4.9	4.1
Marseilles	0.5	...	0.1	...	...	...	...	...	3.5	2.5
Ottawa	...	...	0.3	...	...	...	...	...	2.9	2.8
La Salle	...	...	0.5	0.0	0.0	0.5	0.1	...	5.1	5.1
Peru	...	2.7	...	1.7	...	...	...	...	4.8	4.9
Spring Valley	...	2.0	...	0.0	0.3	...	0.2	...	5.0	5.1
Hennepin	2.2	1.8	...	0.0	0.1	...	...	...	3.4	3.8
Henry	...	2.1	1.0	0.4	0.0	0.4	0.1	...	2.0	3.0
Lacon	...	2.1	...	0.8	0.4	0.4	0.0	5.3	2.0	2.7
Chillicothe	2.3	2.7	0.4	0.0	0.3	0.1	0.5	...	2.0	2.4
Rome	...	1.9	...	0.0	0.2	0.0	0.3	...	2.2	1.9
Narrows (Peoria)	...	4.3	5.7	2.6	3.0	2.4	2.7	...	5.4	5.6
Pekin	...	5.4	5.2	3.3	2.2	2.6	2.8	3.9	...	3.0[g]
Kingston Mines	...	4.1	6.6	3.0	5.5	2.3	2.6	...	...	1.5[g]
Havana	...	3.6	...	1.3	3.8	1.5	3.2	2.9	...	1.0[g]
Browning	...	3.7	...	...	3.9	...	...	...	2.3	1.2[g]
Beardstown	...	4.8	2.7*	2.3	2.7	2.4	2.9	3.9	2.3	1.3[g]

[a] Bartow (1913:40–45).
[b] Hoskins, Ruchhoft, & Williams (1927:114–122) Lowest of monthly mean determinations for July and August 1922.
[c] Greenfield (1925:26–27 and 30–31).
[d] Boruff & Buswell (1929:57–108).
[e] Mondala, *Chairman* (Report of the Illinois River Pollution Commission. 1951:LA 41 Table I Analytical Data of Illinois Sanitary Water Board).
[f] Starrett (Illinois Natural History Survey data).
[g] Mr. Ralph Evans of the Illinois Water Survey furnished the data.
* Samples taken in 1921 rather than 1922.

studied the river in 1921 and 1922, said: "Growth of the city of Chicago, with heavy increase in amount of sewage and of stockyard waste overburdening the already polluted Illinois River, which, with reduced area for overflow, limiting levees, and increased volume, must therefore flow more rapidly in its narrowed channel, with the result that each succeeding year its organic matter is carried farther downstream, before the offensive organic content is sufficiently removed." Richardson believed (1921b:33) that in the 1915–1920 period the southward progression of this offensive condition in the Illinois River was moving at the rate of 16 miles a year.

Conditions upstream from Peoria are much different now from those of about 40 years ago, as a comparison of the oxygen determinations made in 1922 and 1965 indicates (Table 1). This improvement is interesting when one considers the great growth that has been occurring in population and industry in the Chicago metropolitan area. The improvement may have been due to several factors, including the construction and operation of the tremendous sewage treatment plants by the Chicago Sanitary District through a program instituted in 1922, and the lock and dam system built in the 1930's which slowed up the movement of the water. The adoption of better water pollution laws by the state also had its effect.

Hoskins, Ruchhoft, & Williams (1927:25) stated that the total combined domestic and industrial pollution emptied into the Illinois River in 1922 was the equivalent of that from 6,211,471 people. The population equivalent of domestic and industrial wastes entering the river in 1960 (United States Public Health Service 1963) had been reduced to 2,417,000, in spite of expanding human populations and increased industry in the basin. This change reflects the great progress which has been made in the treatment of wastes and indicates the magnitude of work yet to be done.

In spite of the dramatic improvement described above, our oxygen analyses made in 1964 and 1965 (Fig. 3) indicated that most of the river had less than 5 ppm dissolved oxygen. We consider the determinations for the navigation pools to be quite typical for morning samples during warm weather. The downward slopes of the oxygen graphs below the dams (Fig. 3) are similar for all pools but Starved Rock, which is affected on the right bank by effluents from Marseilles and the Fox River. The higher oxygen readings just below the dams, and the declining curves as one proceeds downstream from each dam, indicate that additional oxygen is added as the water passes over and through the dams and locks, and that this is rapidly removed by the high demand for the oxygen caused by the pollutants. Bartow (1913:36) noted a similar increase in oxygen in the river below the Marseilles Dam in 1912.

The similarity of the declines in oxygen below the dams after the initial upsurge indicates that there are still high biological and chemical demands for the dissolved oxygen, and the amount available is at about a breaking point insofar as fish life is concerned.

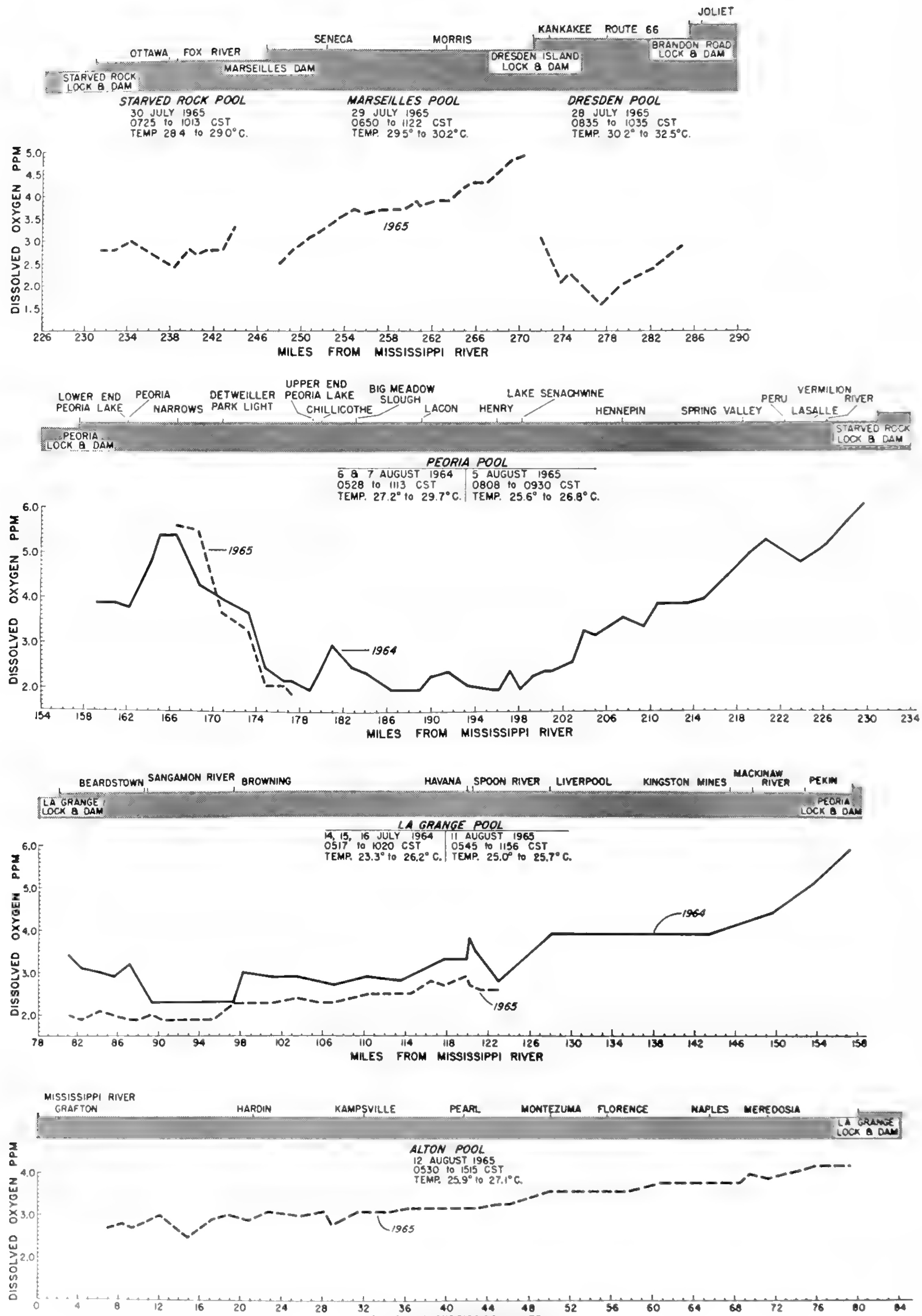

Fig. 3. Dissolved oxygen determinations in the Illinois River from Brandon Road Lock and Dam to Grafton. Broken lines represent readings taken in the summer of 1965; solid lines represent readings taken in the summer of 1964. (Illinois Natural History Survey data.)

The poor oxygen content in the La Grange Pool in the summers of 1964 and 1965 (Fig. 3 and Table 1) probably reflects the effects of additional wastes coming into the river from the Peoria-Pekin area. Conditions were particularly bad during the summer of 1965. This has been a problem of some duration. Boruff & Buswell (1929:54) in reviewing their own and other studies of the BOD (biological oxygen demand) of the river prior to 1928, stated: "Physical conditions, especially below Peoria and Pekin and below this latter city for some miles, tend to show each summer season signs of an increasing pollution load. The extra load that is being added to the river is due to the increased population of the Pekin and Peoria districts, as well as to the very marked increase in industrial wastes." Boruff (1930:5) found that the dissolved oxygen content of the water below Peoria and Pekin remained at a low level.

Our present study of the bottom fauna (Starrett & Paloumpis, unpublished) and of the fishery indicates that some improvement in conditions occurs below the mouth of the Sangamon River at Beardstown. The possible influence of this tributary at times is clearly shown in the cross-section oxygen readings made in 1964 (Fig. 4). In the entire cross section of the Illinois River at Mile 89.3, just above the mouth of the Sangamon, dissolved oxygen was at a value of 2.4 ppm. The cross section at Beardstown at Mile 88.6, also shown in Fig. 4, disclosed a high oxygen content on the left bank below the Sangamon's confluence through Muscooten Bay, and a low content on the right or opposite side. However, our 1965 data do not reflect such beneficial effects from the Sangamon River as were noted in 1964. The longitudinal section (Fig. 4) below the Sangamon's mouth shows that the mixing of the high-oxygen Sangamon water in 1964 did not reach midstream until about Mile 88.

BOTTOM FAUNA

The bottom fauna (benthos) consists of the macroscopic animals which spend all or a part of their lives living on or in the bottom sediments. Certain benthic organisms, such as insect larvae, fingernail clams, and snails, are important food items for larger animals such as fish and ducks (Starrett & Paloumpis, unpublished;

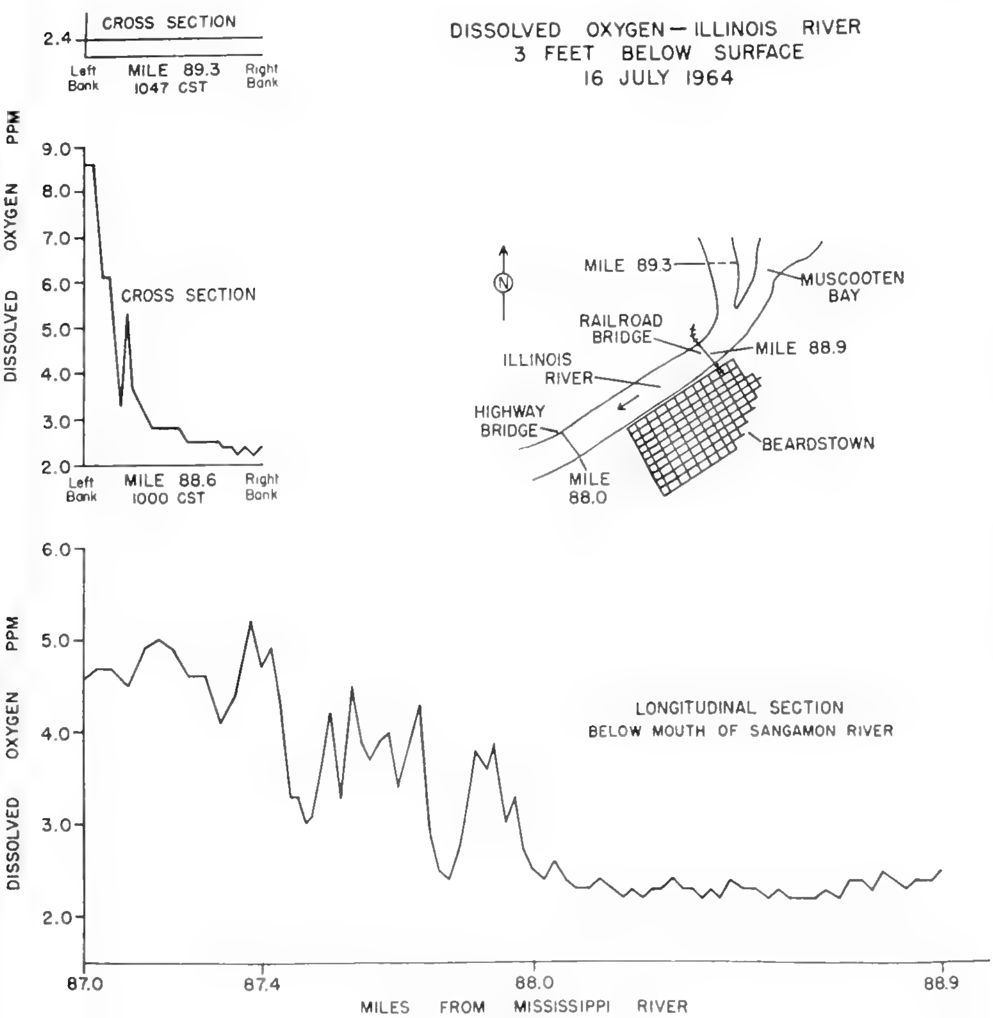

Fig. 4. — A continuous series of dissolved oxygen readings made in the Illinois River with a galvanic oxygen analyzer near the mouth of the Sangamon River. The graphs reflect the increase and mixing of dissolved oxygen in the Illinois River resulting from the effects of a major tributary having a higher dissolved oxygen content. Cross section at Mile 89.3 is above the mouth of the Sangamon River, and cross section at Mile 88.6 is below. (Illinois Natural History Survey data.)

Anderson 1959:338–339). Much of the Illinois River (as well as its adjoining bottomland lakes) is now characterized by populations of pollution worms of the family Tubificidae. However, some of the original diversity of benthic organisms, such as immature insects, clams, snails, leeches, moss animals, and the like, does exist in some parts of the river and its lakes.

Reduction in the abundance of the clean-water animals would be expected to have an adverse effect on animals which rely on them for food, and, as we shall see later, this undoubtedly has happened.

Changes which have occurred since 1913 in the zones of pollution based on the bottom fauna are shown (Fig. 5). The chart shows that approximately half of the river in the La Salle-to-Beardstown section in the 1913–1915 period contained principally clean-water benthic forms, whereas in the 1964–1965 period most of the organisms in the same section of the river were pollution worms, which are poor food for fish and ducks.

Fingernail clams (Sphaeriidae) occurred in large numbers in the Illinois River and some of its bottomland lakes up to 1954 (Paloumpis & Starrett 1960:423–425, and unpublished). The cause for the virtual disappearance of these important food items is not known, but there are strong indications that it was a pollution complex of some kind. These tiny clams (Fig. 6) still occurred in the river below the mouth of the Sangamon at Beardstown in 1964 (Starrett & Paloumpis, unpublished).

Snails of the genera *Campeloma* and *Pleurocera* also occur at the present time in greater abundance in the lower river than elsewhere, but we collected a few living specimens (*Campeloma*) in 1964 from the river channel below Henry by means of an otter trawl. In Quiver Lake, above Havana, Paloumpis & Starrett (1960:425) found that a small snail (*Cincinnati emarginata*) disappeared simultaneously with the fingernail clam. In the lower part of this lake, which is properly a part of the river, all species of snails decreased from 10.76 grams per square foot (exclusive of shells) in 1952 to 6.07 grams per square foot in 1954, and none in 1964 (Starrett & Paloumpis, unpublished).

Starrett & Paloumpis did not take midge larvae abundantly anywhere in the river in 1964 and 1965. At times they were more abundant in fish stomachs than in the benthic collections, especially in the Peoria Pool. It is possible that seasonal variations and local concentrations of larvae may have accounted to some extent for this disparity.

Burrowing mayflies (*Hexagenia*) were considered by Richardson (1928) to be clean-water organisms in the Illinois River. According to Hunt (1953:55) nymphs of *Hexagenia limbata* were unable to withstand stagnant conditions when the dissolved oxygen dropped below 1

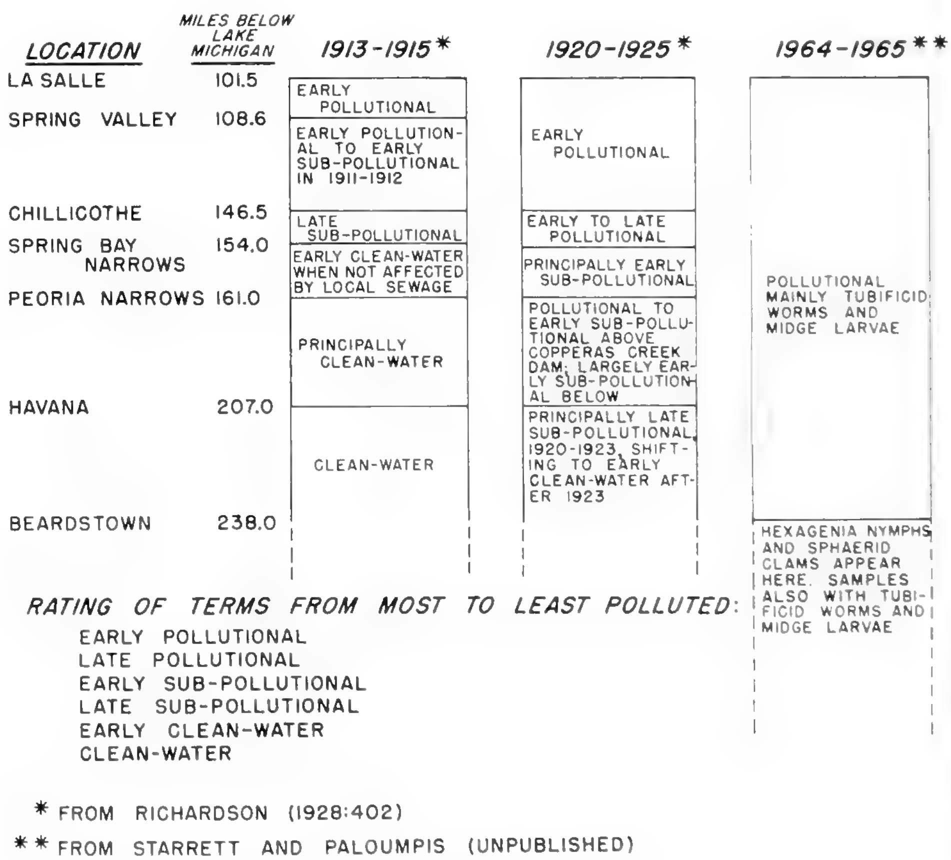

Fig. 5. — Historical change in pollution of the Illinois River as indicated by bottom fauna samples. (From Richardson, 1928, and Starrett & Paloumpis, unpublished.)

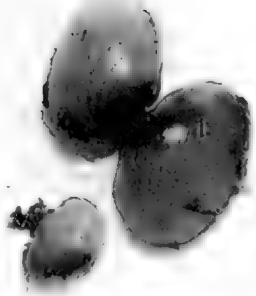

Fig. 6. — Fingernail clams, important food items for some fish and birds, have virtually disappeared from the river above Beardstown.

ppm. In 1913 and 1915 Richardson (1925:381) collected an occasional *Hexagenia* nymph in middle and lower Peoria Lake; after 1915 he did not find any in the river above Havana.

Mayfly emergences can be spectacular when millions of these insects are drawn to lights and may concentrate in such numbers as to be hazardous to traffic. Such emergences have been characteristic of many parts of the Illinois River. The last time we observed a large emergence at Havana was in 1949. Paloumpis & Starrett (1960:419) collected *Hexagenia limbata* nymphs in the 1950's at Quiver Lake, and in most summers during the early 1950's they saw subimagos at or in the immediate vicinity of the lake. Since the late 1950's we have not observed any mayfly emergences at the lake and Starrett & Paloumpis (unpublished) did not collect any nymphs there in 1964. They collected some *Hexagenia*, though, in 1964, in the river below Beardstown and in the Alton Pool.

The predominant organisms in the 1964–1965 benthic samples were pollution worms and these were quite abundant, even in the samples from below Beardstown where both mayfly nymphs and fingernail clams were taken (Starrett & Paloumpis, unpublished). In 1915 at Lake Matanzas, below Havana, Richardson (1921a:506–507) collected only 4.4 worms per square yard, whereas Paloumpis & Starrett (1960:430) in 1953 took 11,007 per square yard in the same area.

Such drastic changes in the benthic populations as those described above can be accounted for only by the accumulative effect of pollution in the bottom muds of the Illinois River waters. Such changes may not be shown by chemical analyses.

AQUATIC VEGETATION

Within the last 15 years there have been unusual changes in the aquatic vegetation of the Illinois River and its bottomland lakes. Today there is a vastly different picture in the vicinity of Havana from that painted by Kofoid at the turn of the century. Flag and Thompson lakes disappeared in the early 1920's, the result of the building of levees, drainage, and cultivation.

Kofoid (1903:236) stated: "The aquatic environment at Havana impresses the visiting biologist who for the first time traverses its river, lakes, and marshes, as one of exceedingly abundant vegetation, indeed almost tropic in its luxuriance. . . . He will find acres upon acres of 'moss,' as the fishermen call it — a dense mat of mingled *Ceratophyllum* and *Elodea* choking many of the lakes from shore to shore, and rendering travel by boat a tedious and laborious process. . . . The carpets of *Lemnaceae* will be surprising, and the gigantic growths of the semiaquatic *Polygonums* will furnish evidence of the fertility of their environment."

The first big change in aquatic vegetation came shortly after Kofoid had completed his study, with the 1900 diversion of Lake Michigan waters into the river.

Richardson (1921b:46) recorded the disappearance of aquatic plants from Peoria Lake in 1920 as follows: "The luxuriant growths of coarse aquatic plants (Potamogeton, Ceratophyllum, Scirpus, Vallisineria, etc.) that covered several square miles of Peoria Lake at midsummer and autumn levels between 1910 and 1914, and their rich fauna of small invertebrates along with them have disappeared now altogether in the upper and middle lake except for an occasional scraggly clump at the very edge. In the lower lake, a thin patch of Potamogeton and Ceratophyllum, covering less than two acres, was still growing in a small springy slough. . . ."

Thompson (1928:304) reported that pondweeds (*Potamogetons*) and other large aquatic plants in Peoria Lake, the river, and connecting sloughs and lakes downstream, disappeared almost completely between 1915 and 1920. But about 1922 pondweeds began to reappear and increase rather rapidly in many areas of Peoria Lake.

Purdy (1930:113) stated that in 1921 Peoria Lake held some growths of pondweeds and algae, but these were so slight as to be overlooked by the casual observer.

From the late 1930's to the middle 1950's, in some places along the central stretches of river there was an abundance of aquatic vegetation, but this has now almost completely disappeared. The reasons for this are not clearly understood. There may be some inimical materials in the waters now, and it appears that the siltation of the last decade has been a factor. Siltation affects aquatic plants adversely in two ways: it produces a turbidity which reduces the penetration of light and inhibits photosynthesis, and it creates bottom conditions which make it difficult or impossible for various species of plants to obtain anchorage when they are buffeted by wave action.

The importance of wave and fish action in resuspending sediment particles in Lake Chautauqua has been pointed out by Jackson & Starrett (1959). During the spring of 1953 they found that, with an increase in wind velocity from light to strong, suspended particles increased more than fourfold (162 to 700 turbidity units). The actions of bottom-feeding fish also caused a resuspension of sediment particles. Because it takes from 7 to 12 days for much of this sediment to settle from Lake Chautauqua, this lake (as with most such lakes in the Illinois River valley) is in a highly turbid state most of the time.

Sago pondweed (*Potamogeton pectinatus*) is more tolerant of reduced light than most other aquatic plants. In spite of this, Bellrose (1941:261–263) found that from 1938 to 1940 sago pondweed in Lake Chautauqua did not thrive in water more than 48 inches deep, and was absent in water more than 56 inches deep. Later, at the same lake, Jackson & Starrett (1959:159) reported that sago pondweed grew best when the maximum water depth was about 3 feet.

Sedimentation of Lake Chautauqua was accelerated by the great spring floods of 1943 and 1944. Beds of aquatic plants, which had declined slightly from 1938 to 1942 (Bellrose 1941:243, and unpublished) were almost wiped out by the high turbid waters of the two following flood years. Probably because additional silt was deposited as a "false bottom" over the previous "firm bottom," aquatic plants never did return to their former luxuriance in Lake Chautauqua. For all practical purposes, longleaf pondweed (*Potamogeton americanus*), coontail (*Ceratophyllum demersum*), and bushy pondweed (*Naias guadalupensis*) were lost as important items in the lake's ecology. Sago pondweed is the only plant which has been common since the 1943 flood. It varies in abundance in Lake Chautauqua annually, depending on the depth of water in May and June; low water during this period has favored a fair growth during some summers. The most extensive recent growth occurred with the low, stable water levels of 1956 when the beds covered 1,237 acres early in the fall.

The Peoria Dam, put into operation in December, 1938, stabilized low water levels in Peoria Lake, and coontail, bushy pondweed, and sago and longleaf pondweeds, as well as wild celery (*Vallisneria spiralis*), increased greatly in the 1940's, with a peak abundance in 1949. Early in the autumn of that year aquatic plant beds were lush, covering several thousand acres of this 10,000-acre lake. After 1949 these beds declined in vigor and abundance until, following a small gain in 1952 and 1953, the lake has been almost completely barren of these plants.

At first this deterioration was attributed to spring floods, such as those that may have affected the Chautauqua flora. However, aquatic plant beds failed to recover when water levels were favorable to growth (with the exception of 1952 and 1953), and this reduces the possibility that floods were solely involved in their decline.

There is evidence that factors other than turbidity may be responsible for the eradication of aquatic plants in certain areas. Coontail, longleaf and sago pondweeds, and wild celery have disappeared from the Starved Rock Pool since the 1940's and have not returned, even though in many years since then the transparency of the water has been adequate for their growth. Their failure to reappear suggests that factors other than a lack of water clarity were responsible; at other lakes increase in water transparency has been simultaneous with an increase in vascular aquatic plants.

The level of Rice Lake was artificially raised 2 or 3 feet in the mid-1940's. When this rise occurred the aquatic and marsh plants began to disappear. By 1950, 360 acres of river bulrush (*Scirpus fluviatilis*) had dwindled to less than 100. By 1956 only 20 acres were left. Both coontail and white waterlily (*Castalia tuberosa*) increased at first with lessened competition from American lotus. However, as the marsh disappeared and wave action increased, this churned up the bottom, and coontail declined from 522 acres in 1950 to none in 1960. White waterlily went from 90 acres to zero in the same period.

Several years ago water levels were raised in Spring Lake, not now connected with the river, to enlarge the lake area for recreation. This increased depth was accompanied by a loss of about 200 acres of coontail and an equal area of river bulrush marsh.

Clearing of bottomland forests for agriculture eliminated such food-producing trees as pecans and oaks which furnished food for some ducks.

FISH

At Havana, on the middle stretch of the Illinois River, some of the elderly citizens still talk of the special trains that used to bring Springfield anglers to Havana for a day's fishing. They also recall the carloads of live fish that were once shipped out of Havana to the New York City market.

Largemouth bass (*Micropterus salmoides*) were abundant enough in the river-bottom lakes so that one could make wages by catching them with a cane pole for the local market. In 1897, 13,061 pounds of bass were handled commercially at the Havana fish markets (Cohen, Bartlett, & Lenke 1899:7). Between 1899 and 1908 the commercial yield of largemouth bass increased 322 percent (Forbes & Richardson 1919:149–150).

During the past half-century man has so seriously damaged the habitat that the once great fishery at Havana, and elsewhere along the river, is now but a fraction of its former size. Increase in turbidity and sedimentation, chronic pollution, decrease in aquatic vegetation, virtual disappearance of fingernail clams, and reduction of food habitat through drainage have contributed to this change.

Perhaps the most important change in the fish fauna was the introduction of the carp (*Cyprinus carpio*) in the 1880's. Carp fitted well into the new environment and soon became the most important commercial species, adapting to many of the changes in the river. The fishery of the river reached its peak in 1908, when about 24 million pounds of fish were taken commercially. Carp made up nearly two-thirds of this catch.

The great increase in the commercial fishery starting at the turn of the century appeared to result from the increase in water because of the diversion from Lake Michigan, the increased nutrients made available to fish-food organisms, and the population explosion of the carp.

Since 1908 the Illinois River fishery has been declining (Fig. 7); data in this depth are not available for sport fishes.

The gains in water area available to fish, brought about by the diversion of Lake Michigan water, began to be offset after 1907 by the drainage of bottomland lakes. The 1913 area was about the same as it was in 1897, prior to diversion (Forbes & Richardson 1919: 154). In addition to these losses due to draining, conditions were further aggravated by the increase in sedimentation discussed earlier. Pollution from the Chicago and the Peoria-Pekin metropolitan areas has had serious effects on the fish and fish-food organisms since the peak of the fishery in 1908. The upper river was more drastically affected than the part below Utica. Between 1912 and 1917 pollution completely wiped out the fish life above this city (Thompson 1928:301).

Forbes & Richardson (1913:517, 521–522) stated that near Morris (Marseilles Pool) in August and September of 1912 the river "was 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. . . . In August and September, 1912, [Marseilles] 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. . . . 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."

In the summer of 1923 the river was practically anaerobic as far down as Chillicothe, with conditions virtually impossible for the existence of fish (Greenfield 1925:24–25).

There has been a change toward the better in the upper river since then. Today fish are found living in the river above Utica. The goldfish (*Carrasius auratus*), an exotic fish not present in the river prior to 1908, now occurs commonly in the upper reaches, together with carp, black bullheads (*Ictalurus melas*), emerald shiners (*Notropis atherinoides*), and other less abundant species. The return of fish life to this part of the river during the late 1930's followed the better treatment of Chicago wastes and the slowing of the river's current following the building of the navigation dams.

From a comparison of modern studies with those made before 1908, it appears that we may have lost 18 species of fish from the Illinois River (Starrett & Smith, unpublished). Many species now occur less abundantly than in former years.

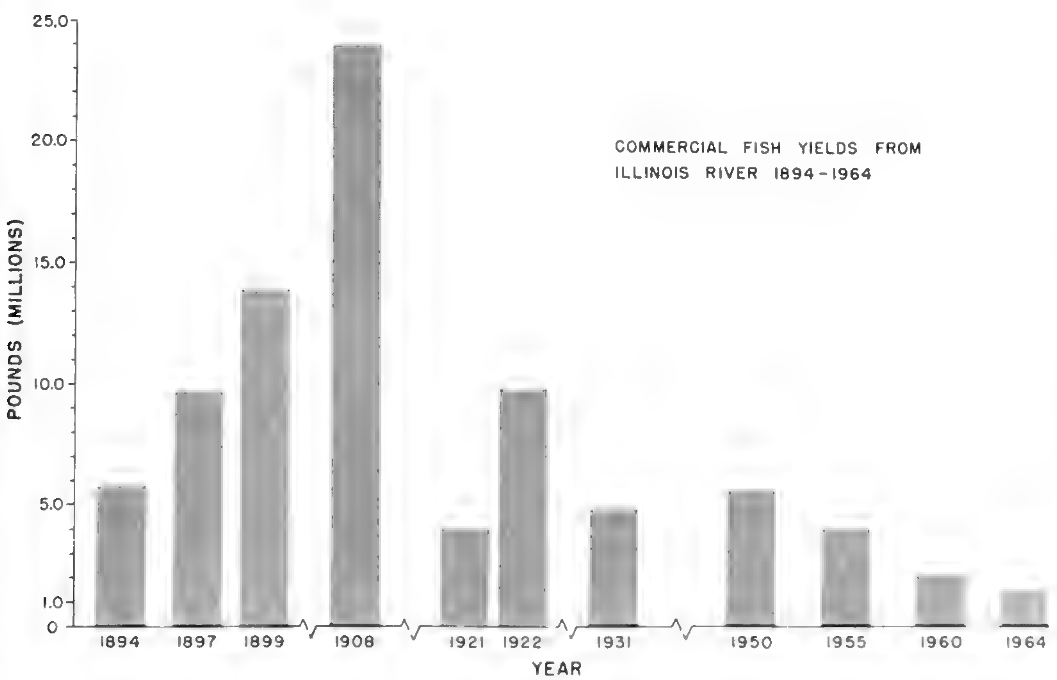

Fig. 7.—Changes in commercial fish yield in the Illinois River from 1894 to 1964. (Data based on published federal fisheries statistics and observations made by the Illinois Department of Conservation and Natural History Survey. Data for 1955, 1960, and 1964 from Starrett, Lopinot & Harth, unpublished.)

In the past 15 years the commercial fishery of the middle river, from Hennepin to Beardstown, has shown a sharp decline. The commercial yield in this stretch has dropped from 5.07 million pounds in 1950 (Starrett & Parr 1951:18) to 0.91 million pounds in 1964 (Starrett, Lopinot, & Harth, unpublished), a reduction of 4.16 million pounds. Because of the condition of the water in the river, the commercial fishery above Hennepin has been limited to the activities of one part-time fisherman who fishes near the mouth of the Fox River near Ottawa.

No attempt will be made here to discuss the condition of the populations of all fish species living in the river, but certain important species are included for closer scrutiny.

Carp

Since carp is the only species of fish that occurs abundantly in all sections of the river it has been used in our studies as an indicator of the effects of pollution. Much of the decline in the commercial catch since 1950 has resulted from the scarcity of carp of commercial size (17 inches or more in total length) in the middle section of the river. Small carp are often abundant in this section but most of them disappear before attaining commercial size. The commercial catch of carp in the Alton Pool has changed little since 1950.

There are two noticeable effects of pollution on this species. First, the length-depth ratio of individuals goes up with increasing pollution. By dividing the depth into the standard length, an index is obtained which, if 3 or greater, indicates that the fish is too thin for commercial uses. Any index under 3 would indicate a satisfactory commercial fish. Second, carp exhibit a rachitic bone malformation (an abnormality characterized by malformed heads and gill covers) known as a "knothead" condition. This becomes more conspicuous (Fig. 8) with increased pollution.

Thompson (1928) found that carp developed the knothead condition in association with the polluted condition of the river during and following World War I. Fig. 9 shows the percentages of the carp population having the knothead condition in various parts of the river, as reported by Thompson (1928:302) and in our checks in 1963. Upstream from Peoria, conditions were similar in 1926 and 1927 to those in 1963. The absence

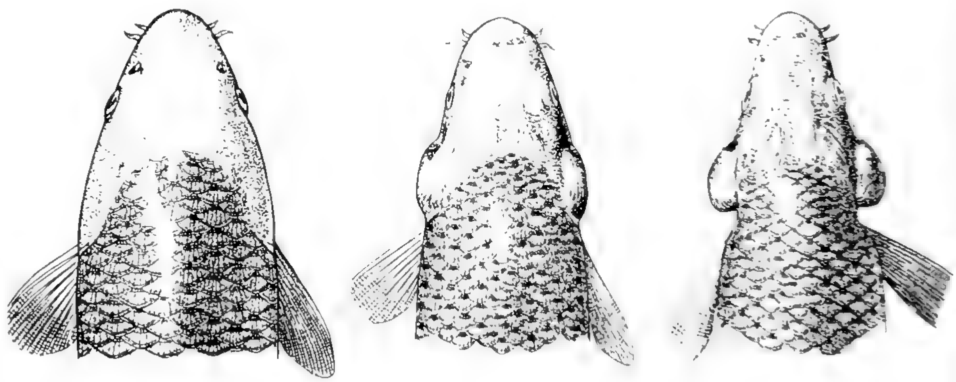

Fig. 8. — Knothead condition in carp. Left, normal; center, moderate knothead condition; right, extreme knothead condition. (From Thompson, 1928.)

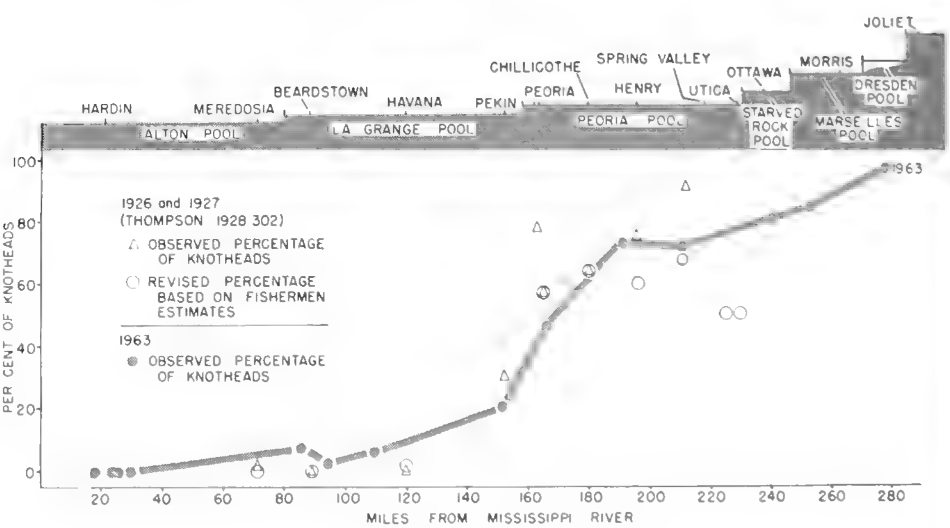

Fig. 9. — Percentage of knotheads in carp populations in the Illinois River in 1926 and 1927 (Thompson, 1928) and in 1963. (Illinois Natural History Survey data.)

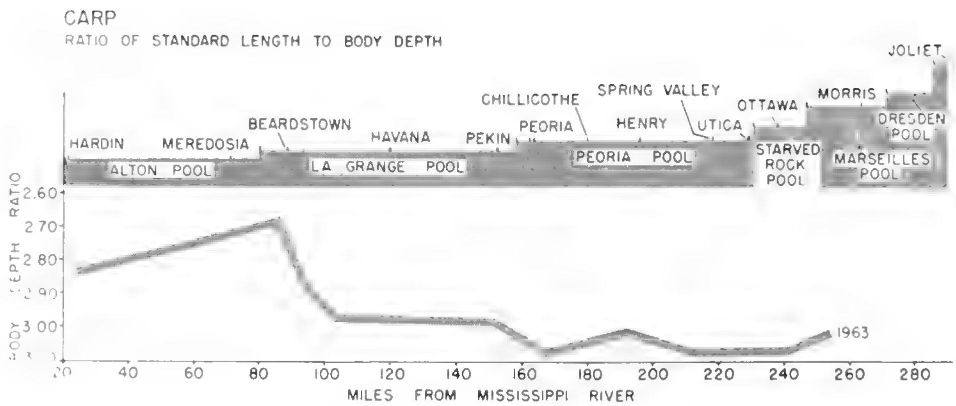

Fig. 10. — Ratio between standard length and body depth in carp in 1963 from Hardin to Morris. Note the change in length-depth ratio at Beardstown. (Illinois Natural History Survey data.)

of fish life above Utica in the 1920's prevented Thompson from extending his study as far upstream as we did at the later date. The percentage of knothead carp between Beardstown and the Peoria-Pekin area was greater in 1963 than it was in 1926 and 1927, indicating a greater pollution load in this stretch of the river. Stating this another way, it appears that the pollutional factors in the river responsible for this condition in carp have not increased above the Peoria-Pekin area, but that they have moved on downstream toward Beardstown since Thompson's observations were made.

The length-depth ratios of carp caught in our autumn 1963 Illinois River collections clearly indicate a sharp distinction between specimens taken above and below Beardstown (Fig. 10). Those below this city had ratios less than 3, and above it the ratios were 3 or more. We suspect that this difference may be due in part to the elimination of fingernail clams above Beardstown. Starrett & Paloumpis (unpublished) have found these mollusca regularly in the stomachs of carp collected in the lower river.

Carp in the middle and upper river are subject to lower dissolved oxygen conditions than those in the lower river. It is possible that the life expectancy of the fish above Beardstown is reduced because of periods of stress resulting from oxygen deficiency. These two factors — loss of fingernail clams plus low dissolved oxygen — could explain the dearth of commercial-size carp in the middle and upper reaches of the Illinois River.

Catfishes

Black bullheads are still abundant in the river, particularly in the middle and upper stretches. These fish, together with carp, furnish most of the river fishing for pole-and-line fishermen from Morris downstream. Channel catfish (*Ictalurus punctatus*) have declined in abundance in the river since 1899 as evidenced by the following commercial fishing statistics: 241,000 pounds in 1899 (Forbes & Richardson 1920:183), 105,554 pounds in 1950 (Starrett & Parr 1951:18), and about 98,000 pounds in 1964 (Starrett, Lopinot, & Harth, unpublished). Most of the catfish are now taken in the lower river.

Buffalofishes

The buffalofishes of the genus *Ictobius* are now found mainly in the middle and lower sections of the river. Commercial catch statistics indicate that these important fishes have declined in the past 65 years, with the decline being the most rapid in the last 15. The 1964 commercial catch was only about half that of 1950.

Crappies

Our data indicate very little change in crappie (*Pomoxis annularis* and *P. nigromaculatus*) populations in the lower river since 1942. However, the decline in the middle river has been alarming. A Natural History Survey crew in 1942 (Thompson & Hansen, field notes) caught six times more crappies in nets than we were able to take by the same method in the middle river in 1964. At Bath, by electrofishing, we caught 14 crappies per 30 minutes of fishing in 1962, and only 4 in the same time in 1964. We suspect that the drastic decline has been due to the low oxygen conditions in association with the low water levels of the past few years.

Bluegill

The bluegill (*Lepomis macrochirus*) has declined in our river collections even more than have the crappies. The take of bluegills in our 1942 fishing in all pools was 33 times greater than in 1964.

Largemouth Bass

We have already mentioned the abundance of this fish at the turn of the century. Other than in a few bottomland lakes, sport fishing for largemouth bass is now rare in the Illinois River. In 1962 we made a few sizable collections from some parts of the middle and lower river. In 1963 and 1964 our electrofishing catch was substantially less in most parts of the river. The decline has been related to pollution and the loss of good habitat, as in the case of other sport fishes.

WATERFOWL

Our emphasis, earlier in this report, on the great reduction in the quantity of vascular water plants has a special application here. These organisms form the base of the food pyramid upon which many other kinds of life depend. Crustaceans and aquatic insects occur abundantly on water plants. Such animals, as well as the plants themselves, form a part of the diet of various aquatic birds. The absence of these and other aquatic organisms can become limiting factors for some waterfowl populations. The disappearance of the fingernail clams and other bottom fauna created a drastic loss in the food supply of most diving ducks that inhabited the Illinois River valley.

Anderson (1959:316) found that mollusca made up more than 85 percent of the diet of lesser scaup ducks (*Aythya affinis*). The ring-necked ducks (*Aythya collaris*) made mollusca about 25 percent of their diet, and the food of canvasbacks (*Aythya vallisineria*) was made up of about 9 percent mollusca.

The combined loss of aquatic plants and bottom animals has drastically affected the numbers of diving ducks that use the Illinois during their migrations. Just as the loss of mollusca apparently caused problems with the lesser scaup, the loss of vegetation in Spring Lake, near Manito, has affected other species. Coontail provided food for several thousand redheads (*Aythya americana*) during the spring migration. Now the redheads are forced to seek food elsewhere. Peoria Lake, once the scene of the greatest fall concentration of diving ducks in Illinois, has suffered an almost complete loss of these birds.

Many dabbling duck species as well, such as the widgeon (*Mareca americana*) and the gadwall (*Anas strepera*), are well known to be dependent on water plants for food.

Let us briefly examine some population statistics for a few important duck species.

Lesser Scaup

Fig. 11 shows the yearly change in lesser scaup populations in both the Illinois and Mississippi river valleys from 1946 to 1964. Both rivers are included to indicate the possibility of change of duck populations from one valley to the other. Prior to 1955 the bulk of the fall population of this species was concentrated in the Illinois River valley. A tremendous decline occurred among the lesser scaups stopping along the Illinois in 1955, and numbers have remained insignificant since then. This reduction is synchronous with the disappearance of fingernail clams. It would appear that, after 1956, some elements of the Illinois River scaup population gradually shifted to the Mississippi. Although this shift could account for a part of the previous Illinois River population, Fig. 11 indicates that the total population for the state has been substantially reduced. We might infer that the Mississippi River does not contain enough food to support a population of lesser scaup such as was

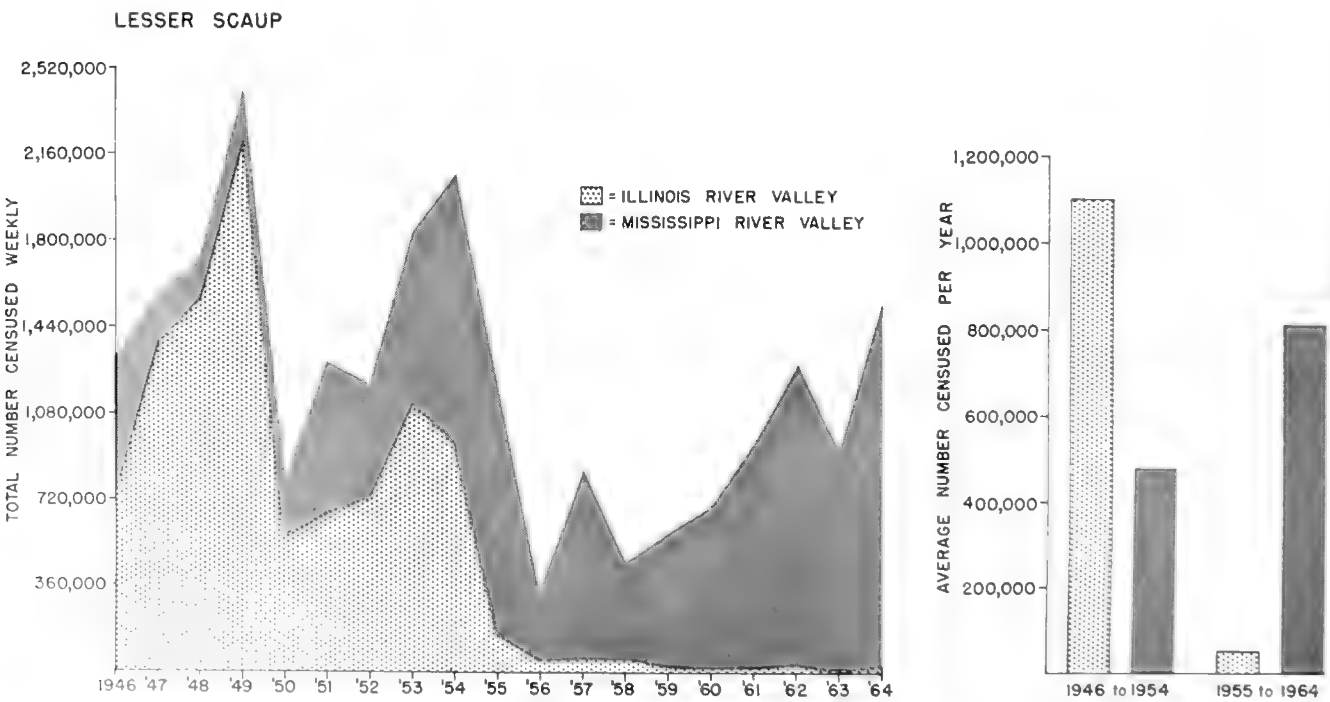

Fig. 11. Changes in lesser scaup duck populations on the Illinois and Mississippi river valleys from 1946 to 1965. The reduced populations after 1954 coincide with the virtual disappearance of the fingernail clams from the river above Beardstown. (Illinois Natural History Survey data.)

present on the combined rivers from 1946 to 1954, for their decline was greater than that for the flyway as a whole.

Ring-necked Duck

Ring-necked ducks were at a peak in numbers in 1949 when aquatic plants reached maximum abundance in Peoria Lake (Fig. 12). With the decline in abundance of both aquatic plants and mollusca in the Illinois River valley, populations of these ducks declined. In the 1955–1964 period the number of ring-necked ducks did not decline proportionately so much as did the lesser scaups. The ringneck seemed to be better able to use the flooded moist-soil plants for food. Moreover there was some decline in the populations of this species in the Mississippi area for several years after 1955. The decline probably reflects a known decrease in flyway population from out-of-state causes, for there was no commensurate deterioration in habitat conditions in the Mississippi valley.

Canvasback

Populations of this species slumped as badly as did those of the lesser scaup following the loss of plant and animal food resources from the Illinois River valley (Fig. 13). The canvasback population in the Mississippi River valley increased during the 1955–1964 period, following the great disappearance of these birds from the Illinois system, but the total population for the state is still far below the pre-1955 level. Canvasbacks in the Mississippi River section of Illinois are forced to feed almost entirely on animal life because of the scarcity of aquatic vegetation, yet food-habit studies (Anderson 1959; Cottam 1939) show their preference for aquatic plant foods.

The paucity of plant-food resources in the Mississippi River section probably limits the numbers of canvasbacks to a level far below that accommodated by both river valleys in the early 1950's.

Ruddy Duck

The ruddy duck (*Oxyura jamaicensis*) declined in numbers with the decline in aquatic plants and mollusca (Fig. 14), but this decline was proportionately less than in other diving ducks, possibly because of this species' propensity to feed on aquatic insect larvae (Anderson, loc. cit.). Insects have not as a group suffered catyclismic losses as have the mollusca in bottomland lakes. Therefore more animal food to the liking of ruddy ducks remains available in this valley. The Mississippi River seems to have absorbed a part of the Illinois River population, as in the case of other diving ducks, but it appears that the "carrying capacity" of the Mississippi may not be sufficient to overcome the loss of the food resources in the Illinois.

Mallard

Populations of this common duck (*Anas platyrhynchos*) in the Illinois and Mississippi river valleys do not show the same trends as do the diving duck populations, or those of the dabblers dependent on aquatic vegetation. Although mallard populations declined after 1955, this decline occurred almost equally in both valleys; no

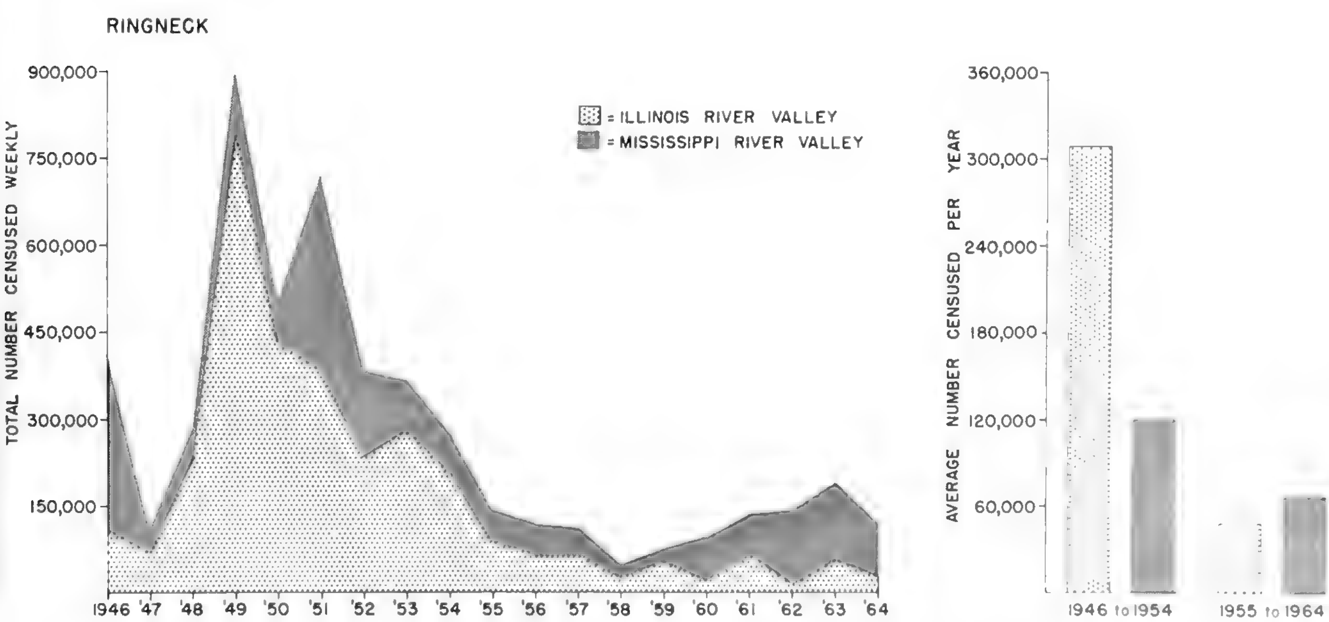

Fig. 12. — The ring-necked duck declined in abundance in the Illinois River following the loss of the mollusc food resource and the reduction in aquatic vegetation. (Illinois Natural History Survey data.)

drastic reduction occurred solely in the Illinois River valley (Fig. 15).

The lower mallard population in Illinois following 1955 is attributed almost entirely to loss in production resulting from drought on the northern plains breeding grounds. The decline in mallard numbers in Illinois did not parallel the loss of aquatic plant and animal food resources. The mallard in Illinois feeds mainly on waste corn and the seeds of moist-soil plants (Anderson 1959); its sustenance is more stable, being to a large extent independent of animal life or aquatic plants.

Mallards have suffered a greater diminution because of drought on the northern plains than have most of the diving ducks; lesser scaup and ring-necked ducks in

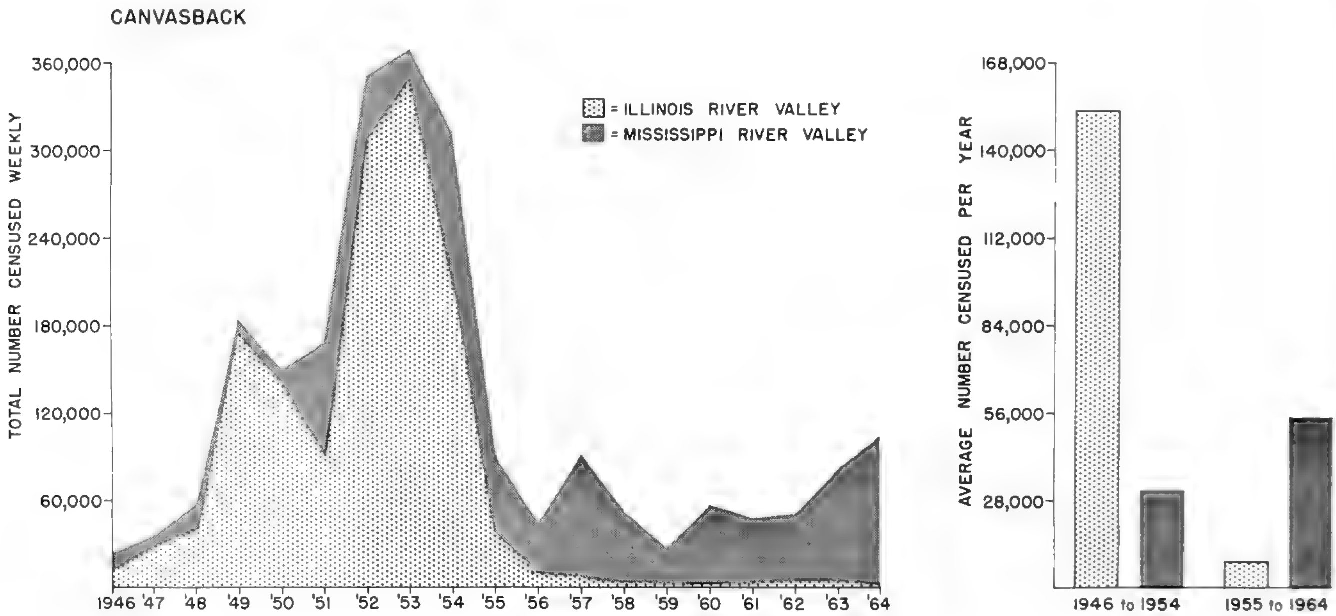

Fig. 13. — Canvasback duck populations declined drastically in the Illinois River valley following the near disappearance of aquatic vegetation and mollusca. (Illinois Natural History Survey data.)

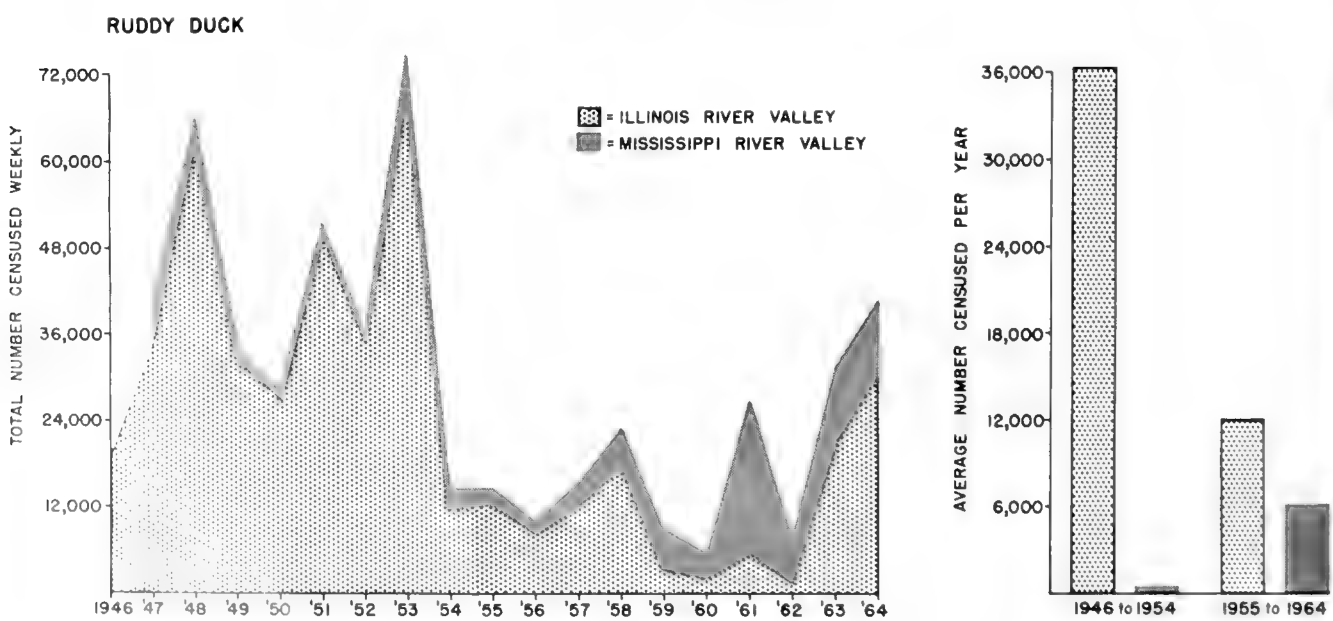

Fig. 14. — Ruddy ducks feed on both small mollusca and aquatic insect larvae. Because aquatic insect larvae did not decline in abundance so much as the mollusca, these ducks persisted in greater numbers, proportionately, after 1954 than did other diving ducks. (Illinois Natural History Survey data.)

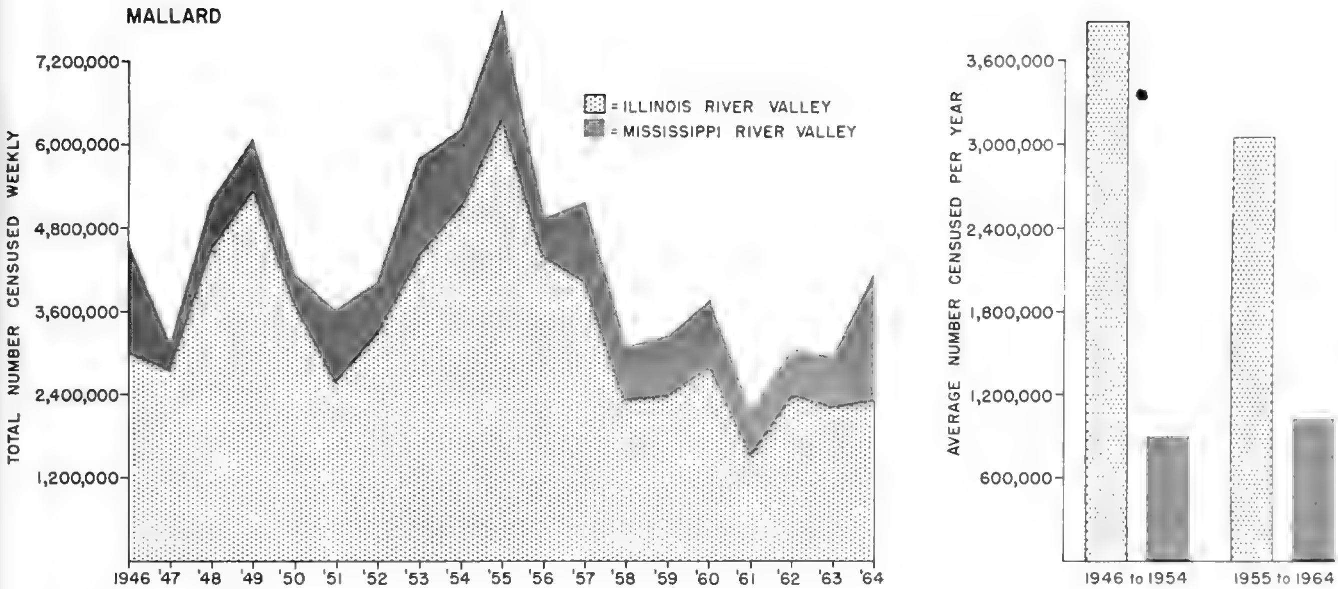

Fig. 15. — The mallard duck feeds primarily on plant foods, largely seeds of moist-soil plants and waste crop grains, so its population was not affected by the loss in mollusca and aquatic vegetation. The population decline in Illinois reflects the continental trend for this species. (Illinois Natural History Survey data.)

particular have escaped severe drought losses. In spite of their greater productivity during this drought period, the lesser scaups and ring-necked ducks, as well as other diving ducks in the Illinois River valley, declined in numbers proportionately much more than the mallard.

The difference in the geographic and yearly population change between the mallard and the diving ducks fortifies our belief that the post-1955 diving duck population loss is directly related to the loss in food resources resulting from silting, and from urban and industrial pollution of the Illinois River and bottomland lakes.

To generalize, it would appear that recent environmental changes in the Illinois River, due to activities of an enlarging human population, have produced disastrous consequences on food resources for diving ducks as well as for some dabblers. From the mid-1950's to the present, a combination of soil pollution plus industrial and domestic pollution appears to have eliminated as a functional part of the environment the important aquatic plant and animal life necessary for the support of populations of many species of ducks. These may not be the only factors involved; we do know that in certain places the raising of water levels, for example, has contributed to the decline of aquatic vegetation.

OTHER BIRDS

A study of any group of species of birds will show fluctuations in numbers from year to year. Some of these changes in bird populations in the Illinois River valley, although conspicuous, cannot be traced to the deterioration of water quality in the river. For example, the prothonotary warbler (*Protonotaria citrea*) was abundant near Chautauqua Lake 15 years ago and is now moderately rare. It is a cavity-nesting, insectivorous species, and at the time of its abundance there were many dead willows along the edges of the lake. The warblers used holes in the trees for nesting. As the trees decayed and fell, the numbers of the birds decreased, and the logical explanation for this population reduction is the disappearance of nesting sites.

Changes in some other species may have a more direct relationship to changes in the river.

Cormorants

Each autumn during the 1940's and the early 1950's there was a large flight of double-crested cormorants (*Phalacrocorax auritus*) down the Illinois River valley. The migrants usually arrived between October 5 and 9. Many thousands remained until early November, conducting fishing drives in the larger bottomland lakes. On October 16, 1950, we estimated that there were 15,000 cormorants on the lakes in the valley between Spring Valley and Meredosia.

The largest single flight of cormorants was observed on October 7, 1940, when an estimated 12,000 passed Havana. Another flight of approximately 9,500 passed that city on October 9, 1949.

A rapid decline in the numbers of cormorants visiting the Illinois River valley occurred after 1950. The largest passage in 1955 occurred on October 14, when 4,000 were estimated. By 1958 the great passage of cormorants had dwindled to only 300 which were observed

TABLE 2.—Approximate number of nests of great blue herons and American egrets in heronries in the Illinois River valley, 1958–1964, based on counts made from a circling light aircraft.

Location of Nesting Colony	1958		1962		1964	
	Great Blue Heron	American Egret	Great Blue Heron	American Egret	Great Blue Heron	American Egret
Lake Depue	250	250	250	300	75	120
Wise's Lake	60	0	0	0	0	0
Pekin Lake	125	125	280	340	60	75
Clear Lake	0	0	110	0	100	110
Ingram Lake	250	0	0	0	0	0
Meredosia Bay	90	0	500	0	150	0
Total	*775*	*375*	*1,140*	*640*	*385*	*305*

on October 5. From 1959 to 1965 very small numbers of cormorants, usually fewer than 200, have been observed at any one time in the autumn. On October 18, 1965, only 22 cormorants were observed on an aerial inventory of water birds in the Illinois River valley. This was the largest number seen in 1965.

We do not know the cause of this decrease in numbers of cormorants migrating through the Illinois River valley, but somewhere along the line a great change in their environment must have occurred.

Herons and Egrets

There is a subjective feeling that the great blue heron (*Ardea herodias*) exists on the Illinois River in diminishing numbers, and it appears fairly certain that although the numbers of American egrets (*Casmerodius albus*) increased until 1962 there has been a decline since then. Our data, however, cover such a short span of time that they do not present a strong basis for evaluating long-term population trends (Table 2). Nesting populations of these two species have fluctuated considerably from 1958 to 1964.

Counts of great blue heron and American egret nests were made at several heronries along the Illinois River in June, 1939. A direct comparison of these nest concentrations with those of more recent times is not possible, for several of them have been vacated and new ones created. However, the nest data suggest that the numbers of great blue herons have declined and that the numbers of American egrets have increased. Only 17 egret nests were found in four heronries in 1939, while 305 were located in three of the heronries in 1964.

CONCLUSION

An attempt has been made in the preceding pages to make comparisons which relate measurable changes in fish and wildlife populations of the Illinois River and its bottomland lakes to human activity during the past three-quarters of a century. Even though a tremendous amount of biological data is available for the river, there are still many areas where we know very little concerning the organisms which live in or have lived in this habitat.

Some things become apparent from this study. Nothing in our physical environment ever remains static; change is the rule. But in this period in history when people are gaining more and more mastery over their environment, they have bent their intelligence toward making unusual changes that may benefit them temporarily but may be deleterious when a longer period is considered.

It is unrealistic to delay doing things which benefit people until we know all of the possible side effects which may go along with these actions. If we were to do this there would never be any progress. But when such side effects become apparent and are not good, and there are ways of circumventing them, we do not use our intelligence if we fail to make corrections.

It is difficult to believe that so much has happened to the Illinois River and its floodplain since Kofoid published his comprehensive work in 1903. Starting with the diversion of Lake Michigan waters into the river in 1900, the ecology of this stream has been changed drastically several times. This diversion added to the fish habitat in the lower stretches and removed it completely in the upper river. Drainage enterprises removed half of the floodplain that the river once used and eliminated fish and waterfowl habitat. Navigation dams created new water areas while destroying important waterfowl marshes. Domestic pollution has fluctuated up and down as new sewage treatment plants have been activated and then found to be inadequate as the rising tide of human population in the basin caught up with them. Chemicals have been released into the waters from developing industries on the river's banks and in the watershed.

Although these actions have caused conditions to fluctuate widely, the net result has been an ever-diminishing biological resource as the aquatic habitat and its inhabi-

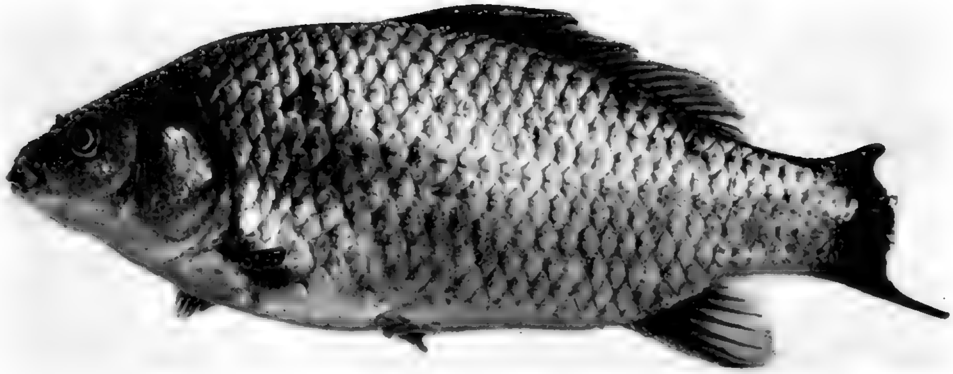

Fig. 16. — A carp-goldfish hybrid collected from the polluted upper Illinois River. Note the eroded tail and fins.

tants have been degraded by the activities of man (Fig. 16). Here and there man has tempered this degradation — wildlife refuges and public hunting and fishing grounds have been established, and management of some areas by hunting clubs has produced better habitats than existed prior to this activity.

We trust that the deleterious trends now apparent in the Illinois River can be changed. Some of the knowledge of how to do this is now available. More must be gained. There must be the desire on the part of agriculture, municipalities, industry, and individuals to translate present knowledge into action.

LITERATURE CITED

Anderson, Harry G. 1959. Food habits of migratory ducks in Illinois. Illinois Natural History Survey Bulletin 27(4):289–344.

Barrows, Harland H. 1910. Geography of the middle Illinois valley. Illinois Geological Survey Bulletin 15. 128 p.

Bartow, Edward. 1913. Chemical and biological survey of the waters of Illinois: Effect of Chicago sewage on the Illinois River. University of Illinois Bulletin 10(36), Water Survey Series 10:30–45.

Bellrose, Frank C. 1941. Duck food plants of the Illinois River valley. Illinois Natural History Survey Bulletin 21(8):237–288.

Boruff, C. S. 1930. Illinois River studies 1929–1930. Illinois Water Survey Circular 9. 8p.

———, and A. M. Buswell. 1929. Illinois River studies 1925–1928. Illinois Water Survey Bulletin 28. 127 p.

Brown, Carl B., J. B. Stall, and E. E. DeTurk. 1947. The causes and effects of sedimentation in Lake Decatur. Illinois Water Survey Bulletin 37. 62 p.

Cohen, Nat H., S. P. Bartlett, and A. Lenke. 1899. Report of the Illinois state fish commissioner from October 1, 1896, to September 30, 1898:3–42.

Cottam, Clarence. 1939. Food habits of North American diving ducks. USDA Technical Bulletin 643. 140 p.

Ellis, M. M. 1936. Erosion silt as a factor in aquatic environments. Ecology 17(1):29–42.

———. 1937. Detection and measurement of stream pollution. U.S. Bureau of Fisheries Bulletin 22(48):365–437.

Forbes, Stephen A. 1911. Chemical and biological investigations on the Illinois River, midsummer of 1911. A preliminary statement made to the American Fisheries Society, St. Louis, Missouri, October 3, 1911. Illinois State Laboratory of Natural History. 9 p.

———, and R. E. Richardson. 1913. Studies on the biology of the upper Illinois River. Illinois State Laboratory of Natural History Bulletin 9(10):481–574 + 21 pl.

———, and ———. 1919. Some recent changes in Illinois River biology. Illinois Natural History Survey Bulletin 13(6):139–156.

———, and ———. 1920. The fishes of Illinois. Second edition. Illinois Natural History Survey. cxxxvi + 357 p.

Greenfield, R. E. 1925. Comparison of chemical and bacteriological examinations made on the Illinois River during a season of low and a season of high water — 1923–1924. Illinois Water Survey Bulletin 20:9–33.

Hoskins, J. K., C. C. Ruchhoft, and L. G. Williams. 1927. A study of the pollution and natural purification of the Illinois River. I. U.S. Public Health Service, Public Health Bulletin 171. 208 p.

Hunt, Burton P. 1953. The life history and economic importance of a burrowing mayfly, *Hexagenia limbata*, in southern Michigan lakes. Michigan Department of Conservation, Bulletin Institute for Fisheries Research 4. 151 p.

Hynes, H. B. N. 1964. The use of biology in the study of water pollution. Chemistry and Industry, March 14, p. 435–436.

Illinois Cooperative Crop Reporting Service. 1965. Illinois agricultural statistics, annual summary. Illinois Department of Agriculture, USDA Bulletin 65–1, 109 p.

Jackson, Harry Owen. 1954. Limnological investigation of three Illinois bottomland lakes. Master of science in education thesis, Illinois State University, Normal. 99 p.

———, and William C. Starrett. 1959. Turbidity and sedimentation at Lake Chautauqua, Illinois. Journal of Wildlife Management 23(2):157–168.

Jefferson, Thomas. 1787. Notes on the state of Virginia. J. Stockdale, London, p. 13.

Kenton, Edna. 1925. The Jesuit relations and allied documents. Selected and edited by Edna Kenton. Albert and Charles Boni, New York.

Keup, Lowell E., William Marcus Ingram, Jack Geckler, and William Bliss Horning II. 1965. Biology of Chicago's waterways. U.S. Department of Health, Education and Welfare, Public Health Service, Division of Water Supply and Pollution Control, Environmental Health Series. Public Health Service Publication No. 999–WP–32. 20 p.

Kofoid, C. A. 1903. Plankton studies. IV. The plankton of the Illinois River, 1894–1899, with introductory notes upon the hydrography of the Illinois River and its basin. Part I. Quantitative investigations and general results. Illinois

State Laboratory of Natural History Bulletin 6(2):95–635 + 50 pl.

Mondala, Stanley, *Chairman*. 1951. Report of the Illinois River Pollution Commission. Submitted to the 67th General Assembly of the State of Illinois, January 30. Processed.

Mulvihill, Wm. F., and L. D. Cornish. 1929. Flood control report: An engineering study of the flood situation in the state of Illinois. Illinois Division of Waterways, Springfield. 402 p.

Paloumpis, Andreas A., and William C. Starrett. 1960. An ecological study of benthic organisms in three Illinois River flood plain lakes. American Midland Naturalist 64(2):406–435.

Purdy, W. C. 1930. A study of the pollution and natural purification of the Illinois River. II. The plankton and related organisms. U.S. Public Health Service, Public Health Bulletin 198. 212 p.

Richardson, Robert E. 1921a. The small bottom and shore fauna of the middle and lower Illinois River and its connecting lakes, Chillicothe to Grafton: its valuation; its sources of food supply; and its relation to the fishery. Illinois Natural History Survey Bulletin 13(15):363–522.

———. 1921b. Changes in the bottom and shore fauna of the middle Illinois River and its connecting lakes since 1913–1915 as a result of the increase, southward, of sewage pollution. Illinois Natural History Survey Bulletin 14(4):33–75.

———. 1925. Changes in the small bottom fauna of Peoria Lake, 1920 to 1922. Illinois Natural History Survey Bulletin 15(5):327–388.

———. 1928. The bottom fauna of the middle Illinois River, 1913–1925. Its distribution, abundance, valuation, and index value in the study of stream pollution. Illinois Natural History Survey Bulletin 17(12):387–475.

Stall, J. B., and S. W. Melsted in cooperation with Illinois Agricultural Experiment Station. 1951. The silting of Lake Chautauqua, Havana, Illinois. Illinois Water Survey Report of Investigation No. 8.

Starrett, William C., and Arnold W. Fritz. 1965. A biological investigation of the fishes of Lake Chautauqua, Illinois. Illinois Natural History Survey Bulletin 29(1):1–104.

———, and Sam A. Parr. 1951. Commercial fisheries of Illinois rivers: A statistical report for 1950. Illinois Natural History Survey Biological Notes 25. 35 p.

Tarzwell, Clarence M. 1958. Oxygen relationships in streams: Dissolved oxygen requirements for fishes. U.S. Department of Health, Education and Welfare, Public Health Service, Robert A. Taft Sanitary Engineering Center Technical Report W58-2:15–24.

Thompson, David H. 1925. Some observations on the oxygen requirements of fishes in the Illinois River. Illinois Natural History Survey Bulletin 15(7):423–437.

———. 1928. The "knothead" carp of the Illinois River. Illinois Natural History Survey Bulletin 17(8):285–320.

United States Public Health Service. 1963. Report on the Illinois River system, water quality conditions: Part I, Text. U.S. Department of Health, Education and Welfare, Public Health Service, Division of Water Supply and Pollution Control, Great Lakes — Illinois River Basins Project. 155 p.

Weibel, S. R., R. J. Anderson, and R. L. Woodward. 1964. Urban land runoff as a factor in stream pollution. Water Pollution Control Federation Journal 36(7):914–924.

(89820—8000—6-66)