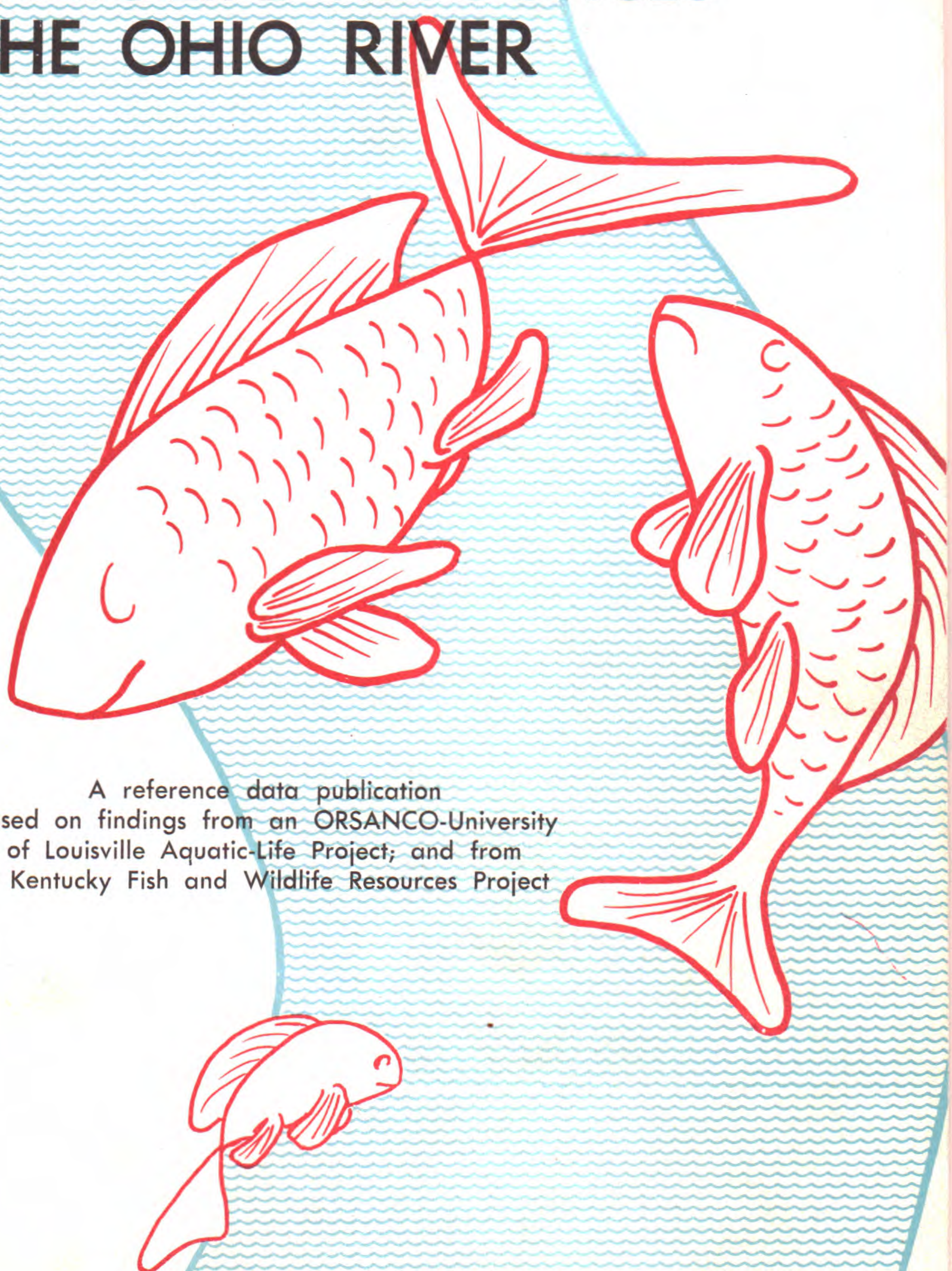
AQUATIC-LIFE RESOURCES OF THE OHIO RIVER



A reference data publication
based on findings from an ORSANCO-University
of Louisville Aquatic-Life Project; and from
a Kentucky Fish and Wildlife Resources Project

OHIO RIVER VALLEY WATER SANITATION COMMISSIC
414 Walnut Street, Cincinnati 2, Ohio

AQUATIC-LIFE RESOURCES

OF THE OHIO RIVER

An inventory and evaluation of fish populations, limnological conditions, commercial fishing, and sport fishing, with historical notes.

A reference data publication based on findings from an ORSANCO-University of Louisville Aquatic-Life Project, and from a Kentucky Fish and Wildlife Resources Project

OHIO RIVER VALLEY

WATER SANITATION COMMISSION

414 Walnut Street, Cincinnati 2, Ohio

1962

UNIVERSITY OF LOUISVILLE
LOUISVILLE 8, KENTUCKY

COLLEGE OF ARTS AND SCIENCES
DEPARTMENT OF BIOLOGY

25 January 1962

Dr. Edward J. Cleary
Executive Director and
Chief Sanitary Engineer
Ohio River Valley Water
Sanitation Commission
414 Walnut Street
Cincinnati 2, Ohio

Dear Dr. Cleary:

I have the honor of transmitting to you herewith, on behalf of the Department of Biology of the University of Louisville and the Kentucky Department of Fish and Wildlife Resources, a revision, designed for publication, of the final report on the Aquatic-Life Resources of the Ohio River submitted on August 15, 1960.

The latter was a joint report of the activities and findings of the ORSANCO-University of Louisville Aquatic-Life Resources Project and the Kentucky Department of Fish and Wildlife Resources Investigations of the Ohio River Fishery.

It has been a privilege to be associated with you and the Ohio River Valley Water Sanitation Commission in this endeavor.

Respectfully submitted,

UNIVERSITY OF LOUISVILLE

William M. Clay

William M. Clay
Head of Biology Department
and Director of Project

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PREFACE AND ACKNOWLEDGMENTS

This study was sponsored by the Ohio River Valley Water Sanitation Commission (ORSANCO), through the University of Louisville with funds derived from Public Law 660, and the Kentucky Department of Fish and Wildlife Resources under Dingell-Johnson Project F-13-R.

The study was under the direction of Dr. William M. Clay, Head of the Department of Biology of the University of Louisville, and Bernard T. Carter, Director of the Division of Fisheries of the Kentucky Department of Fish and Wildlife Resources.

The chief field investigators in ichthyology were Dr. Louis A. Krumholz and W. L. Minckley from the University of Louisville and James R. Charles from the Kentucky Department of Fish and Wildlife Resources. These men collected and identified the fishes and compiled the data on relative abundance and distribution (Section III). Section IV, Creel Census Data, and Section V, Commercial Fishing, were prepared by Mr. Charles.

Limnological investigations were carried out successively by Dr. G. A. Cole (November, 1957 to June, 1958), John G. Weise (June, 1958 to August, 1959), and Dr. Daniel F. Jackson (September, 1959 to end of project). Section I, Historical Notes on Fish Fauna, and Section II, Limnological Observations, were written primarily by Dr. Jackson.

The survey of taste and odor qualities of Ohio River fishes was conducted by Mr. Minckley and Dr. Clay, and the report of this survey, Section VI, was prepared by the latter. Section VII, General Summary and Conclusions, was written by Mr. Carter and Dr. Clay. The report was edited by Mr. Carter, Dr. Clay, and W. L. Klein of ORSANCO, with the assistance of Mrs. Sue Ayer, who was also responsible for typing the manuscript.

Many persons have done extensive work in the field, laboratory, library, or cataloguing room. These include Dr. A. T. Hotchkiss, J. P. Ahrens, L. O. Barr, G. C. Blankenbaker, Emmalee Bowers, D. L. Bunting II, H. S. Cavanah, Dorothy Cockerill, Donald A. Distler, William Geiling, David Hadden, W. K. Lindsay, Judith Loring, W. T. Mason, Don McDonald, B. B. Moser, Bobbi Stiers, and Lucille Talken.

Billy Sayle and William Broughton, Fishery Field Assistants, worked with Mr. Charles in the activities carried out by the Kentucky Department of Fish and Wildlife Resources.

The Honorable Minor E. Clark, Commissioner of the Kentucky Department of Fish and Wildlife Resources, and Dr. Edward J. Cleary, Executive Director and Chief Engineer of ORSANCO, were largely responsible for initiating the project and cooperated most generously in providing the facilities of their agencies.

The work of P. R. Fauth in performing the bacteriological analyses is greatly appreciated. W. L. Williams, Superintendent of the Water Treatment Plant, Louisville, Ky., generously extended use of the water-quality data and other resources of the Louisville Water Company.

We extend thanks to Richard Foster Flint and Eugene H. Walker for permission to draw upon their publications for certain illustrations.

We are deeply grateful to the staff of the Ohio River Valley Water Sanitation Commission for encouragement and support throughout the study, and in particular to W. L. Klein and F. W. Montanari, who served as liaison members of the Commission.

Personnel of the following agencies have contributed generously in various capacities to the success of the project: Aquatic Life Advisory Committee of ORSANCO, Illinois Department of Conservation, Illinois Natural History Survey, Indiana Division of Fish and Game, Ohio Department of Natural Resources, Pennsylvania Fish Commission, U.S. Army Corps of Engineers, and West Virginia Conservation Commission.

AQUATIC-LIFE RESOURCES

OF THE OHIO RIVER

SECTION I

HISTORICAL NOTES ON FISH FAUNA

by Daniel F. Jackson

I. HISTORY OF THE OHIO RIVER

The Ohio River has a long and complex history, for its story involves an integral part of the geological history of the eastern United States. The present Ohio River is an amalgamation of streams which had their respective beginnings millions of years ago and which were joined into one mighty river during the Pleistocene.

So great were the changes wrought by glaciers during the Pleistocene Epoch that the history of the Ohio River basin may logically be divided into two major phases. About the first phase, the pre-Pleistocene phase, little is known except in broad outline. During this era the Ohio was a smaller river with headwaters either near Manchester, Ohio, or possibly not farther east than near Madison, Ind. The Monongahela and the Allegheny (which are the present headwaters at Pittsburgh) and the New, the Kanawha, the Big Sandy, and possibly the Licking and the Kentucky, were parts of other drainage systems. But during the second phase great ice sheaths blocked some of these northward-flowing streams and filled their valleys with glacial debris. In finding new pathways to the sea, these rivers were diverted into the Ohio River system.

The great Teays River system shown in Fig. 1 evolved long before the Pleistocene. From headwaters in the Piedmont region of North Carolina and Virginia, the main channel of the Teays followed a generally northwesterly course past the site of the present city of Huntington, W. Va., and on to Fort Wayne, Ind., there to discharge into the valley presently occupied by the Wabash River southward into an arm of the Gulf of Mexico. Later, as the shoreline of the Gulf receded, the Teays probably joined the Mississippi River. Today portions of the valley of the Teays are occupied by the New and Kanawha Rivers and by the Ohio from Huntington to Wheelersburg, Ohio.

The basin of the Teays was separated by a divide in northeastern Ohio and northern West Virginia from that of other streams which flowed more northward into the present St. Lawrence River basin. The Monongahela and Allegheny Rivers represent a portion of the latter system of streams. Upon being added to the Ohio system the Allegheny reversed its direction of flow from northward to southward.

The history of the middle portion of the Ohio is more problematical. Basically, there are two theories. One of these is that the ancient Ohio River headed near the site of the town of Manchester, Ohio, in the same valley which the river now occupies. This upper portion, which is known to geologists as the Manchester River, joined another tributary, the Licking River of Kentucky, just north of the site of Cincinnati, and together these two streams continued northward in the valley of the present Mill Creek to join the Miami River, there to form the Ohio River proper. It may be noted that according to this theory the most distant headwaters were probably those of the Licking River.

According to the other principal theory the Licking, Manchester, and Miami Rivers were portions of the ancient Teays system. If these conditions prevailed, the Miami River flowed northward rather than southward and joined with the Teays at some unknown point near the Ohio-Indiana line.

That portion of the present Ohio River valley between the mouths of the Kentucky River and the Miami River is least well known historically. According to the first theory above, the direction of flow in this portion was the same as at present and the Miami and the Kentucky were portions of the Ohio system. The second theory assigns the Kentucky River to the Teays system and has the direction of flow in the Ohio valley northeastward, in reverse to its present direction of flow, from Carrollton to the mouth of the Miami River. If this is the correct explanation, the ancient Ohio proper headed at a divide near Madison, Ind.

Considerable doubt attaches to this last theory. Jillson (1946) in a report on an abandoned channel of the Ohio River near Carrollton, concluded that the direction of flow in Pliocene times was to the west, as it is today. This would permit a possible third interpretation, namely, that the ancient lower Ohio headed somewhere between Carrollton and Cincinnati and that the Kentucky was already a part of the Ohio system, but that the Licking, Manchester, and Miami Rivers belonged to the Teays system.

In a good account of the Teays River, Janssen (1952) states that the present Ohio River consists of five major parts: "(1) the headwaters portion consisting of the Monongahela and the Allegheny; (2) the reverse flow stretch between Pittsburgh and New Martinsville; (3) the section as far as Huntington, formerly a tributary of the Teays; (4) the bed of the Teays itself from Huntington to Wheelersburg; and (5) the lower river from Wheelersburg to the Mississippi."

II. MAN AND THE RIVER

A. Aboriginal Times

Although there is fragmentary evidence of earlier dwellers or wanderers, the first human inhabitants of the Ohio River valley of whom there is abundant evidence were the people of the Indian Knoll culture. These people lived mainly in the region south of the Ohio River, but a few sites are known in Ohio, southern Illinois, and Indiana (Banta, 1949). One of their outstanding characteristics was such an extensive use of shellfish that their kitchen middens grew into huge mounds upon which their villages existed. Thus they must have relied heavily upon shellfish and fish for food.

These Indians were succeeded by the mound builders, noted for their burial mounds of which the Great Serpent Mound in Adams County, Ohio, and Grave Creek Mound in Marshall County, W. Va., are among the larger and more spectacular examples. The first of the mound-builder cultures, the Adena, was in existence by at least 900 A.D. It was followed by the well-known Hopewell culture. The Hopewells used harpoons and arrows to catch fish (Rau, 1885).

Young (1910) reported: "The streams of Kentucky once abounded in fish. This was particularly true of the Ohio River at its falls near Louisville, and if the vast number of fishhooks and stone sinkers which have been found in that vicinity constitute an index of the presence of fish, then this spot was more abundantly supplied than any other portion of the stream, and was a favorite resort of the aboriginal angler." Since the hook of the aborigine was barbless and often had no eyelet for attaching a line it would seem that considerable skill and effort were required for successful angling. Nevertheless, Young (op. cit.) concluded "that the prehistoric men who lived in Kentucky regarded and used fish as one of the most constant and appetizing of their viands."

B. The Eighteenth Century

In 1770, George Washington commented about his trip on the Ohio River near Wheeling Creek: "The party threw out some lines, and found a catfish of the size of our largest river catfish, hooked to one of them in the morning, though it was one of the smallest kinds here" (Showalter, 1932).

More information concerning the early fish fauna of the Ohio River may be found in Colonel John May's account of his journey down the Ohio in 1778: "River fish were so plentiful at Pittsburgh that the tavern keeper gave his boarders fish for dinner every day....There are seven of us and we have not been able to eat more than one fish a meal." He saw two "perch"[1] that together weighed 40-1/2 lbs. When his boat was held up at Marietta, he noted that "The catfish and perch[2] make such a noise under my ship that they frequently keep me awake half the night" (Green, 1929). Apparently even the large catfish, weighing from 30 to 50 lbs., had delicious flavor indicative of excellent quality of fish present in the river (Cutler, 1787).

Johann D. Schopf (1788) presented observations on the Ohio River in 1783 and 1784 as part of a two-volume work which was published in Germany. In his monograph he reported: "The low water and the shortness of our stay prevented my seeing anything of the fishes of this region. There is a species of sturgeon[3], which is described as differing from the sturgeon of the Hudson and the Delaware. People tell about large trout[4] and pike[5], which are like those found in other parts of the country. Yellow perch[6] are said to be found there. A sort of catfish, somewhat similar to the catfish so common in the Delaware (Silurus catus L.)[7], is found weighing from 30 to 50 lbs., and some declare that farther down the stream they have seen specimens of this species weighing from 80 to 100 lbs. The spawning fishes, particularly the shad (Clupea alosa L.)[8], which in April and May go far upstream in nearly all the rivers of the eastern coast, are almost entirely lacking in these western rivers. A particular kind of turtle, which, however, I could not get a sight of, lives in the Ohio and its branches. Some call it the soft-shelled and others the green turtle[9]. Snapping turtles[10] are also found in the waters of the Ohio."

One of the most complete descriptions of the fishes of the Ohio River during the latter part of the eighteenth century appears in David Zeisberger's account of the history of the North American Indians. Zeisberger was a Moravian missionary who had a mission home beside the Muskingum River in 1779-1780. He reported the following observations, with parenthetical remarks by Hulbert and Schwarze (1910):

"(1) Pike are of uncommon size and generally known (Stizostedion vitreum)[11].

(2) The black fish[12]...is one of the best flavored (refers to a species of sucker).

(3) The buffalo fish...is about a foot and a half or even two feet and its breadth five or six inches (large-mouth buffalo, small-mouth buffalo, or black buffalo).

(4) The catfish--a good fish to eat. In the Muskingum there are no large specimens of this fish. In the Ohio, on the other hand, they grow to an unusual size. In Pittsburgh, a man who had gone

to sleep in his canoe was dragged into the water by the catfish and lost his life. Man and fish were found close together several days later. (Among the valuable food species are _Ictalurus punctatus_[13], the blue cat, _Ameiurus lacustris_[14], the Mississippi cat, _Ameiurus nebulosus_[15], the bullhead, and _Leptops olivaris_[16], the mudcat. The Ohio catfish sometimes weighs 60 or 70 lbs.)

(5) The sturgeon is the largest of the fish in the Muskingum. The largest caught here were from three to three-and-a-half feet in length (_Acipenser rubicundus_)[17].

(6) There is a kind of fish with a narrowly formed mouth, armed with sharp teeth, almost like the bill of a duck....The Indians do not use it for food (_Lepisosteus osseus_, the gar pike).

(7) Another kind resembles the catfish very much. It has no scales. This also has a broad, plain beak like the bill of a goose, almost the length of a hand. This it uses to dig in sand or slime in search of food. The mouth opens below (_Polyodon spathula_, the spoon-bill cat).

(8) The white perch is short and broad. It has scales and is good to eat (_Aplodinotus grunniens_, the freshwater drum).

(9) The yellow perch is not broad, but longer than the last-named, has prickly fins and sharp teeth like those of a pike. It has a yellowish appearance and is one of the most palatable of fishes (_Perca flavescens_)[18].

(10) Eels are rarely found.

(11) There is another variety of fish or whatever one may call it, resembling a small catfish, but having four short legs. It has a wide mouth and is about a foot and a half in length (_Necturus maculatus_[19], water dog, and _Cryptobranchus alleganiensis_, hellbender.)"

John Filson (1784) commented on the fishes of the Ohio River in Kentucky: "The western waters abounded with fish and fowl. The fish common to the waters of the Ohio are the large size buffalo-fish.[20] In Kentucky, salmon[21] has been taken which weighed 30 lbs. Perch[22], garfish[23], suckers, sunfish, eels[24] and other hookfish are abundant. Trout, shad, and herring are not present in the western waters."

St. John de Crevecour, an agriculturalist from New Jersey, described his trip from Pittsburgh to Louisville in a letter dated August 26, 1784, with the following: "We were kept busy catching fish which were very abundant. You can hardly imagine the singular charm this pleasure adds to this new mode of navigation. The perch[25], the jack[26], the catfish, weighing 80 lbs., the buffalo[27] weighing 20 lbs., is the best of all. Below the falls at Louisville, the sturgeon and green turtle[28] are taken" (McMeekin, 1946).

General Richard Butler mentioned the falls at Louisville in his journal on Dec. 8, 1785. He found that "the lower part of the falls had a great abundance of swans, geese, ducks and pigeons, plenty flying over. Many fine fish are also present, but the people generally too indolent to catch them, though in great need."

The pike[29] was reported as "king of fishes in the western waters." On July 2, 1788, Judge Gilbert Devoll took a pike in Muskingum River which weighed nearly 100 lbs. "He was a tall man but the tail of the fish dragged on the ground when it was suspended from his shoulder. This enormous fish was served up on the Fourth of July at a public dinner" (Hildreth, 1848).

Before the nineteenth century very little was known about the quality or quantity of the water in the Ohio River. However, notations in the records indicate the transparency of the Ohio River at the confluence with the Mississippi River provided a striking contrast: "The pure water of the Ohio and the dirty soapsuds of the Mississippi being poured together" (Forman, 1888).

Nearly the same situation existed at the source of the Ohio. According to Way (1942), the Allegheny had the reputation of being "the most transparent body of water in the world." Bissell (1949) quoted Louis Evans in 1750 as reporting: "The Monongahela is much distinguished by its Royley water, which joins the Ohio near the confines of this province. The land between the forks of the Ohio (present site of Pittsburgh) is low swampy ground, much infested with venomous serpents and Muskeetose, and subject to be overflowed every spring."

Although thermometers were in use during the eighteenth century, there appear to be no records of water temperature for the Ohio River. One may speculate, however, that the water would have been cooler in the summer than it now is because of the trees shading all the tributaries of the Ohio and those covering the banks of the Ohio itself.

Extreme variations in flow are evident from early records. Congressman John Randolph from Virginia commented on this to the House of Representatives in 1799. "The Ohio River! The Ohio River! Frozen over one half of the year and dried up the other!" La Salle, in 1669, was stopped from going any farther down the Ohio because of low water and the barrier formed by the falls of the Ohio at Louisville, Ky. General Butler (1785) recorded in his journal that at a site near Marietta, Ohio, there was less than two feet of water. Early records of high water in the Ohio River indicate Pittsburgh had a 41-foot flood in 1763, and Cincinnati a 75 to 76-foot flood in 1772 or 1773 (Klein, 1954).

In general, the picture of the river at this period is one of plenty of fishes in the river, pure water throughout most of the drainage basin, gravelly, rocky, or sandy bottoms, lush growth of aquatic plants in the crystal-clear, shade-covered stream; in short, an unspoiled region. And so little populated that scarcely 30 families could be found in the space of 400 miles (Michaux, 1805).

C. The Nineteenth Century

John James Audubon (1836) gave an informative account of his 1808 journey downstream from Louisville, Ky.: "Now and then a large catfish rose to the surface of the water in pursuit of a shoal of fry, which, starting simultaneously from the liquid element like so many silvery arrows, produced a shower of light, while the pursuer with open jaws seized the stragglers, and with a splash of his tail, disappeared from our view. Other fishes we heard uttering beneath our bark, a rumbling noise, the strange sounds of which we discovered to proceed from the white perch[30], for on casting our net from the bow, we caught several of that species, when the noise ceased for a time....The margins of the shores and of the rivers were at this season amply supplied with game. A wild turkey, a grouse, or a blue-winged teal could be procured in a few moments....Every tree was hung with long and flowing festoons of the different species of vines, many loaded with clustered fruits of varied brilliances, their rich bronze carmine mingling beautifully with the yellow foliage, which now predominated over the yet green leaves, reflecting more lively tints from the clear stream than ever landscape painter portrayed or poet imagined."

Similarly Michaux (1805) reported several beds of mussels were also abundant in the Ohio, Allegheny, and Monongahela. One species, _Muletta_ sp., was used to make buttons. He further commented: "The Ohio abounds in fish of different kinds; the most common is the catfish, _Silurus felis_[31], which is generally caught with a line, and weighs sometimes a hundred pound. This fish is also taken with the spear."

The eighth edition of _The Navigator_ in 1814 reported: "The fish of the Ohio are numerous and of various kinds: the black and yellow cat[32], weighing from 3 to 100 lbs.; the buffalo[33], from 5 to 30 lbs.; the pike[34], from 4 to 15 lbs; the sturgeon from 4 to 40 lbs.; the perch[35] from 3 to 12 lbs.; the sucker from 1 to 6 lbs.; a few herrings[36] sometimes caught, and, in the spring of 1805, several shad[37] were caught and sold in the Pittsburgh market, weighing about 2 lbs.; eels[38] and soft-shell turtles[39] are sometimes caught...these ascend the Allegheny and Monongahela Rivers, and their principal branches."

Schultz (1810), in writing about the fishes in the Pittsburgh area, stated: "The Allegheny affords fine pike[40] and catfish; many weighing in excess of 30 lbs. The variety of small fish is limited in the main river (the Ohio). The larger kinds are taken at night by netting in the little bays and eddies." Schultz, however, is one of the few early writers to speak unfavorably of the fishes in the Ohio. He stated (op. cit.): "The Ohio, as yet, has not produced any fish....I am inclined to believe it is not so well stocked with fish as it is represented to be....I have been assured, by respectable gentlemen, that many [catfish] are frequently caught which weigh from 50 to 90 lbs. I have seen a few catfish, buffalo fish[41], perch[42], chub, suckers, and herrings[43]; but no sturgeon or pike." Perhaps Mr. Schultz was a poor fisherman.

At a later date Audubon described his impressions as follows: "Several species or varieties of catfish are found in the Ohio, namely the blue[44], the white[45], and the mudcats[46], which differ considerably in their form and color, as well as in their habits. The mudcat is the best, although it seldom attains so great a size as the rest. The blue cat is the coarsest, but when not exceeding from 4 to 6 lbs. it affords tolerable eating. The white cat is preferable to the last but not so common; and the yellow mudcat[47] is the best and the rarest. Of the blue kind some have been caught that weighed a hundred pounds. Such fishes, however, are looked upon as monsters."

The first scientific investigation of the fishes of this river or the entire region was made in 1818 and 1819 by C. S. Rafinesque, who collected fishes from the Ohio River. Up to this time only about 12 species had been properly named from this area. Rafinesque's work, Ichthyologia Ohiensis, although it contains some errors, is still one of the outstanding fish studies in the United States. Ichthyologists are indebted to R. E. Call, who in 1899 reprinted the original text of Rafinesque.

Rafinesque began his monograph by speaking of the "beautiful river." He reported the depth of the Ohio to be "very variable...low water at three feet and high water at about thirty feet." Velocity of the Ohio was reported as gentle, two miles an hour to four miles an hour, except at the falls and riffles. He wrote that at low stages the Ohio was "almost clear, and at all times very salubrious." He reported over 130 islands and many sand bars in the Ohio.

Rafinesque reported 113 species of fishes in his Ichthyologia. Of this number five were not found in the Ohio River basin and ten were based on fraudulent drawings made by John James Audubon. This left a total of 98 fishes. Of this number only 60 were considered valid species by Evermann (1918).

According to the Louisville Daily Dime, May 27, 1844, the editor of the Cincinnati Gazette caught two fine shad[48] while fishing in the Ohio River. The visiting editor was amazed at this event whereupon the editor of the Louisville Daily Dime commented: "It has become so common here for us to eat the fine 'shad' of the Ohio River that we had forgotten that there was anything marvelous in it until reminded of it by the way the editor of the Cincinnati Gazette smacks his lips over the real facts."

Kirtland (1844) reported an alligator gar (Lepisosteus spathula) measuring five feet eight inches long was captured in the Ohio River between Cincinnati and Pittsburgh. About this same time Hildreth (1848) reported the Ohio muskie (Esox masquinongy Ohioensis) was "common in Ohio waters."

The early 1800's had seen a change in the Ohio River itself. In 1811 the first steamboat, the "New Orleans", left Pittsburgh. This advent of a new type of transportation revolutionized the Ohio River and affected every organism living in or near the river. According to Hulbert (1906) there were 63 steamboats on the Ohio in 1819, and 230 by 1832. In 1842, 105 steamboats were launched on the Ohio. In 1811 there were only 40 or 50 coalpits around Pittsburgh. In 1813 coke was introduced for making iron, and in 1813 the Ohio River valley was becoming the industrial center of the new nation.

The United States Army Corps of Engineers began to remodel the Ohio River in 1824 by removing snags and rocks and constructing dikes which resulted in scouring out many sandbars and gravel beds. One of the remaining major obstructions to navigation in the Ohio River was the Falls of the Ohio at Louisville, Ky. Ships could get over the Falls usually only in three months of the year. To overcome this obstacle the Louisville-Portland canal was constructed in 1830, thus permitting passage around the Falls.

In 1861 a low-water year was experienced. The river at Pittsburgh had a depth of 18 inches and at Cairo it was only three feet deep during the lowest period (Hunter, 1949). During this same season horses and buggies crossed the Ohio River at Madison, Ind.

As a result, in 1885, five miles below Pittsburgh a dam was constructed which permitted Pittsburgh to be a harbor even in the low-water season. By 1911, eleven more dams were constructed between Parkersburg, W. Va., and Pittsburgh. Although these dams aided boat navigation, they changed the character of the river and were barriers to fish movement.

From 1831, the rapid rise of industry in the Ohio valley was phenomenal. Coal and steel became king in the Pittsburgh area and the Allegheny, Monongahela and Ohio Rivers lost their purity during the advancement of progress. The same type of picture prevailed at Cincinnati and farther along the Ohio River.

Much of the meat-packing industry of the Ohio River valley in the 1830's was located on Beargrass Creek, a tributary to the Ohio River above Louisville. In the year 1854 up to Dec. 3, 144,000 hogs were slaughtered (Louisville Daily Journal, Monday, Dec. 3, 1854). In 1855, 310,000 hogs were slaughtered (Louisville Daily Journal, Monday, Dec. 31, 1855) for the entire season. The blood and offal from these animals flowed directly into the Ohio River. Beargrass Creek was known as "old crimson." Even today, 1960, "old crimson" still pollutes the Ohio.

Each factory, industry, or city had its own insidious effect on the river. At Louisville, Ky., according to the June 22, 1831, Louisville Daily Focus, a new city ordinance established that "It shall be unlawful for any person or persons to throw into the harbor, any substance or things that will produce a disagreeable smell--and any person thus offending shall be subjected and fined the sum of four dollars." By 1831 the Ohio River at Louisville contained so much drift and soil pollution that plans were undertaken to construct a waterworks to provide cleaner water for the citizenry.

The decrease in woodland cover was evidenced by increased siltation in the river. By 1883, only 18 per cent of the state of Ohio had woodland cover, while in 1853 it was 54 per cent wooded (Diller, 1956). By 1910, most of the harvestable timber had been removed from Kentucky (Courier-Journal, Louisville, Ky., Sept. 23, 1941).

R. E. Call, in 1896, listed 56 species of fishes from the Falls of the Ohio at Louisville, Ky. At this time species such as *Polyodon spathula*, paddlefish; *Acipenser fulvescens*, lake sturgeon; and *Scaphirhynchus platorynchus*, shovel-nosed sturgeon, were reported as being abundant in this area. Evermann (1902) described a new species of shad (*Alosa ohiensis*) which he found in the Ohio River at Louisville, Ky., as well as 20 other species found locally.

By 1900, however, fishing in the Ohio River above the Falls of the Ohio was becoming noticeably poorer. Thwaites (1897) reported the following comment by a shantyboater at Hawkinsport, W. Va., May 14, 1897: "He (the shantyboater) had been in this spot for two years, he said, and sold fish to the daily Parkersburg steamer--when there were any fish. But for six months past he hadn't made enough to keep him in grub and had now and then to go up to the city and earn something. For forty years had he followed the apostle's 'calling on this yere Ohio, and the fishing was never so poor as now--yes, sir!' Hard times had struck his business, just like other folks. He thought the oil wells were tainting the water and the fish wouldn't breed --and the iron slag, too, was spoiling the river and he knew it. He finally produced for us, out of his box, a three-pound fish--white perch[49], calico bass[50], and catfish form his stock in trade; but before handing it over demanded the requisite fifteen cents."

The three fishes named are examples of how the fishes may reflect the changes in the Ohio River as an environment. Among M. B. Trautman's many observations (The Fishes of Ohio, 1957), the following are of interest: (1) The mooneye, Hiodon tergisus, once abounding in the Ohio River, according to Kirtland (1847), was significantly decreasing in numbers. (2) The stonecat, Noturus flavus, according to Jordan (1882), "is now common in the Ohio River." Since 1900 this species has been decreasing (Trautman, 1957). (3) The mud pickerel, Esox americanus, once common in the Ohio River, is now rare. The decline of the mooneye and stonecat indicates that around 1900 the Ohio River was more turbid than it had been in the past, as these species prefer clear water. The mud pickerel inhabits oxbows or marshes containing clear water with much aquatic vegetation. Both these conditions were obliviated by the removing of snags and rocks and the channeling of the river.

D. The Twentieth Century

In 1900 the U.S. census reported 1,250,000 inhabitants along the Ohio River, an increase of 500,000 since the last census in 1880. Eighty per cent of this total increase took place in the Cincinnati-Pittsburgh section of the valley. This rapid increase in population is a reflection of increased industry in and immigration into the Ohio valley. In 1900 only two cities in the Ohio River basin, Canton and Alliance, Ohio, had sewage-treatment plants.

In 1908 an attempt was made in Ohio to prevent pollution in the waters of the Ohio valley. Forty years passed before this became a reality. By the early part of the twentieth century the Ohio River received increasing amounts of pollution. Drainage from coal mines and steel mills made the Monongahela increasingly acid. Oil seepage from the oil fields of Pennsylvania covered the Allegheny with a film of oil. Effluents from tanneries, creameries, meat-packing companies, pulp and paper mills, distilleries, breweries, and the sewage from the towns along the Ohio River formed the obnoxious environment described by Davis (1914). It is of interest to note some of the changes that occurred in the fish fauna of the Ohio River during that time.

One example of the effect of pollution on the fishes may be found in a letter to the editor of the Louisville Courier-Journal from Mr. H. S. Swope of Ashland, Ky. The letter, dated Sept. 20, 1933, begins:

> "My purpose in writing you is to give you a report of the greatest loss of fish from some form of pollution, as far as I know, in the history of the Ohio River.
>
> "About a week ago, I believe it was September 7, I was asked to go down to the river and see the dead fish. These fish were first observed passing down the Ohio at Ashland on the morning of Sept. 7 and continued to pass for two days--reaching the crest of the tide per-

haps sometime in the night of the first day. I did not see the river until the second day, when they had begun to become thinner. I witnessed the most horrible fish destruction that one can imagine. Fishing in the Ohio, I have often heard people say that there were no fish in this river, but when you saw thousand upon thousand of fish of every species and every size floating down the river, one was then impressed with the thought that there were plenty of fish in the river. I do not know how to estimate the numbers of fish, or pounds of fish, but surely ten tons would not be an exaggeration. The white splotch could be seen on the river as far up and down as the eye could see, and they were fairly close together.

"There were literally thousands of these fish. Then on the shoreline one could get close and inspect them, and they would weigh up to twenty or thirty pounds. There were catfish, walleyes, white perch, carp, buffalo, sturgeon, etc. There were thousands of minnows from half an inch long to four inches long. I repeat that there was no species not represented in the slaughter. I am told that this destruction went as far up the river as Wheeling. Wheeling is approximately 130 miles above Ashland. Perhaps you could have some idea yourself as to what the picture would look like, for the Ohio River is one of the largest we have in the United States and I expect close to half a mile wide at Ashland. In connection with this subject I am just through talking to a river captain who was on the river at the time these fish were passing between Ashland and Parkersburg. He tells me that above several of the locks fish were so thick that it looked like you could walk across the river on them.

"Now for the cause. I am told that there were no dead fish above the little Kanawha River, which, as I said before, is about 130 miles above Ashland. This riverman that I have just talked to was of the opinion that this pollution came out of this river in West Virginia. He seemed to think that it was due to dyes from some of the mills on this river. However, the exact cause I do not know. As for the effect, I believe there was not a living aquatic life left in the river, for perhaps a distance of 125 miles below where this pollution occurred. I do not see how there could be, from what we witnessed going down the river. I reported this matter to the Kentucky Game and Fish Department, and naturally they could do nothing. I also reported it to the United States Bureau of Fisheries. They said they could do nothing--it was not in their jurisdiction. Now it can not be denied that someone is to blame for this destruction and I trust, if the cause can be found, that no alibi will pay for it except the maximum penalty which is in the keeping with the crime. There is no law in any state providing a severe enough penalty to pay for this loss. The masses of people and sportsmen will await the results of whatever investigations are made."

Changes in water quality affected not only fish but man. In 1930 and 1931 a tremendous outbreak of intestinal disorders occurred in several cities which used the Ohio River as a source of water supply. By 1936, 1,400,000 people were obtaining drinking water from the polluted Ohio River.

After the nine-foot pool stage was established by the completion of the dams in 1929, the river was changed from a flowing stream to a series of impoundments. These changes permitted greater amounts of suspended matter to settle and provided more ideal conditions for increasing growth of microscopic organisms, mostly algae. These, in turn, increased the problems of objectionable tastes and odors. In many instances, the elimination of these tastes and odors is beyond the ability of water filtration plants.

Hubbard (1953), reporting his adventures in a shanty-boat, at Cincinnati in November, 1946, described the Ohio River as being "unclean everywhere. Even the flowing water offshore where I took the john boat to wash out the mud was foul. We learned at first hand what a city does to a river." The next evening, he further reported: "The water was unclean especially along the shore line. The influence of the city extended further than its limits, but we hoped that another day's run would put us beyond the evident pollution."

In discussing the change in fish abundance during the 1900's, Trautman made particular mention of the paddlefish and the sturgeons. Before 1915 paddlefish were fairly common in much of the Ohio River. From 1925 to 1950, paddlefish were numerous only in the Ohio River west of Portsmouth and in the Scioto River. Before 1915 the "bull-nosed sturgeon" (*Acipenser fulvescens*) were common. Since that time, rarely can a commercial fisherman collect more than two in a day. The "bull-nosed sturgeon" since 1915 are also smaller in size, the maximum rarely being over 30 pounds, while previously individuals were reported to have weighed as much as a hundred pounds. Until 1910, as many as 75 shovel-nosed sturgeon (*Scaphirhynchus platorynchus*) could be taken daily on a trot line as far upstream as Marietta, Ohio. A sharp decline in numbers of this species occurred following the river's impoundment. Among other important fishes which seem to be declining in the Ohio since 1900, according to Trautman (*op. cit.*), are the yellow bullhead, blue catfish, the walleye, and the silver lamprey (*Ichthyomyzon unicuspis*).

Although many of the changes in the aquatic life of the Ohio River have been of an annihilating or reducing nature, there have been some increases in quantity of certain fish species because conditions became better suited for them. Or, perhaps competition had become less or even absent. Trautman (*op. cit.*) has made the following observations: As early as 1850 Kirtland reported the channel catfish (*Ictalurus punctatus*) to be "diffused through waters of Lake Erie and Ohio basin." From 1920 on it has been abundant in the Ohio River. The channel catfish prefers deep water, of low base gradient, and doesn't mind silty bottom, provided the silt accumulation is slow.

The numbers of black bullheads, Ictalurus melas, are increasing because this species prefers a silty bottom with turbid and warm water. The goldeye, Hiodon alosoides, was uncommon in the Ohio River before 1888. Since that time the river has become significantly more turbid and the goldeye has replaced the mooneye, which is not tolerant of turbid waters. The skipjack herring, Alosa chrysochloris, since 1925 has become very abundant and has extended its range into the Pennsylvania section of the Ohio River.

The gizzard shad, Dorosoma cepedianum, was reported as early as 1820 in the Ohio River, but recently it has shown a rapid increase in number. Hubbard (1953) told of his adventure with shad in Gilmore Creek, just below Madison, Ind., in January, 1947. "I reached down into the thick swarm (of fish) expecting them to vanish in an instant. When I raised up the net it held as many fish as I could lift...We learned that the fish were called shad. One day in conversation with two farmers at a deserted house nearby, where we went to get drinking water, we mentioned shad and invited them to come down and get a bucket full. They laughed, said that they sometimes hauled up a wagonload for their pigs."

In reference to the fluctuation among the basses, the spotted bass, Micropterus punctulatus, "outnumbered more than 50 to one the smallmouth black bass in commercial nets, and the largemouth to the spotted bass ratio was even greater" (Trautman, 1957). The spotted bass have always been the predominant bass species in the Ohio River. They like large-sized streams with deep pools and can tolerate some degree of turbidity and silty condition. The changing Ohio seems ideal for this species. The freshwater drum, Aplodinotus grunniens, was abundant in the Ohio until 1860. From 1925 to 1950 the drum significantly declined. Since 1950, however, in areas of the Ohio River where pollution has been corrected, the drum have increased.

In 1948, the states of Indiana, West Virginia, Ohio, New York, Illinois, Kentucky, Pennsylvania, and Virginia formed the Ohio River Valley Water Sanitation Compact. At long last an agency was created to aid the masses of people referred to by Mr. H. S. Swope in his plea for control of pollution in the Ohio River.

The fact that commercial fishing is a going industry in the Kentucky portion of the river, the only state permitting the use of commercial catch methods, is further proof that valuable species do exist in the river. The fishing is centered primarily in the lower section. Most of the catch, catfish and drum, is sold on the local market. In 1958, it is estimated 2,000,000 pounds were taken, with a value of $410,000. This provided full or part-time employment for some 1,200 persons.

NOTES

1. Probably the freshwater drum, *Aplodinotus grunniens* Rafinesque. Because the same common name has often been used for more than one species, we have, after consultation with other ichthyologists, indicated by footnote the probable present-day identification of the species named in the text.
2. Freshwater drum.
3. Lake sturgeon, *Acipenser fulvescens* Rafinesque.
4. Walleye, *Stizostedion vitreum vitreum* (Mitchill), or sauger, *Stizostedion canadense* (Smith).
5. Muskellunge, *Esox masquinongy ohioensis* Kirtland.
6. Walleye, *Stizostedion vitreum vitreum* (Mitchill).
7. White catfish, *Ictalurus catus* (Linnaeus).
8. American shad, *Alosa sapidissima* (Wilson).
9. Soft-shell turtle, *Trionyx* sp.
10. Snapping turtle, *Chelydra serpentina* Linnaeus.
11. Muskellunge, *Esox masquinongy ohioensis* Kirtland.
12. Blue sucker, *Cycleptus elongatus* (LeSueur).
13. Channel catfish, *Ictalurus punctatus* (Rafinesque).
14. Blue catfish, *Ictalurus furcatus* (LeSueur).
15. Brown bullhead, *Ictalurus nebulosus* (LeSueur).
16. Flathead catfish, *Pylodictis olivaris* (Rafinesque).
17. Lake sturgeon, *Acipenser fulvescens* Rafinesque.
18. Walleye, *Stizostedion vitreum vitreum* (Mitchill).
19. Mudpuppy, *Necturus maculosus* (Rafinesque).

20. Buffalo, Ictiobus sp., or freshwater drum, Aplodinotus grunniens Rafinesque.

21. Walleye, Stizostedion vitreum vitreum (Mitchill), or sauger, Stizostedion canadense (Smith).

22. Freshwater drum, Aplodinotus grunniens Rafinesque.

23. Gar, Lepisosteus sp.

24. American eel, Anguilla rostrata (LeSueur).

25. Freshwater drum, Aplodinotus grunniens Rafinesque.

26. Sauger, Stizostedion canadense (Smith).

27. Buffalo, Ictiobus sp., or carpsucker, Carpiodes sp.

28. Soft-shell turtle, Trionyx sp.

29. Muskellunge, Esox masquinongy ohioensis Kirtland.

30. Freshwater drum, Aplodinotus grunniens Rafinesque.

31. Flathead catfish, Pylodictis olivaris (Rafinesque).

32. Flathead catfish.

33. Buffalo, Ictiobus sp.

34. Muskellunge, Esox masquinongy ohioensis Kirtland.

35. Freshwater drum, Aplodinotus grunniens Rafinesque.

36. American shad, Alosa sapidissima (Wilson).

37. American shad (deeper-bodied females).

38. American eel, Anguilla rostrata (LeSueur).

39. Soft-shell turtle, Trionyx sp.

40. Muskellunge, Esox masquinongy ohioensis Kirtland.

41. Any or all three species: Black buffalo, Ictiobus niger (Rafinesque); bigmouth buffalo, Ictiobus cyprinellus (Valenciennes); and smallmouth buffalo, Ictiobus bubalus (Rafinesque).

42. Walleye, *Stizostedion vitreum vitreum* (Mitchill); sauger, *Stizostedion canadense* (Smith); or freshwater drum, *Aplodinotus grunniens* Rafinesque.

43. American shad, *Alosa sapidissima* (Wilson).

44. Blue catfish, *Ictalurus furcatus* (LeSueur).

45. Channel catfish, *Ictalurus punctatus* (Rafinesque).

46. Black bullhead, *Ictalurus melas* (Rafinesque); yellow bullhead, *Ictalurus natalis* (LeSueur); brown bullhead, *Ictalurus nebulosus* (LeSueur).

47. Flathead catfish, *Pylodictis olivaris* (Rafinesque).

48. Mooneye, *Hiodon tergisus* LeSueur.

49. Freshwater drum, *Aplodinotus grunniens* Rafinesque.

50. Black or white crappie, *Pomoxis* sp.

AQUATIC-LIFE RESOURCES

OF THE OHIO RIVER

SECTION II

LIMNOLOGICAL OBSERVATIONS

ON THE OHIO RIVER

by Daniel F. Jackson and John G. Weise

I. INTRODUCTION

Limnological observations of physical-chemical-biological conditions formed a part of the investigation of the aquatic-life resources of the Ohio River. Limnology is now commonly defined as that branch of science dealing with biological productivity of inland waters and with all the causal influences which determine it (Welch, 1948).

The following observations, made from October 1, 1957, to January 2, 1960, are grouped in two categories. The observations in Chapter IV of this section concern seven regions of the Ohio River. Chapter V is a more detailed study of the region in which Louisville, Ky., is located. The seven regions discussed in Chapter IV are shown in Figure 2.

Although many studies have been made of its tributary streams, only a few intensive studies have been made on the Ohio River proper. The reports of Purdy (1922), Frost _et_. _al_. (1924), Phelps (1925), Crohurst (1933), Brinley and Katzin (1942), United States Ohio River Committee (1944), Public Health Service House Document No. 266 (1951, 1958), and the Ohio River Valley Water Sanitation Commission (1957, 1959a), represent the major limnological literature on the Ohio River.

II. PHYSICAL DESCRIPTION

The Ohio River is formed by the confluence of the Allegheny and Monongahela Rivers at Pittsburgh, Pa., and flows southwesterly for 981 miles to its confluence with the Mississippi River near Cairo, Ill. Most of the Ohio River basin is underlain by Paleozoic sedimentary rocks ranging in age from Cambrian to Permian. Coal-bearing members of Pennsylvanian age are present in certain areas of West Virginia, eastern and western Kentucky, Pennsylvania, western Illinois and Indiana. Mean annual precipitation in the valley ranges from 51 inches in the extreme southwestern portion to 43 inches in the extreme northeastern portion, and from 60 inches in the extreme southeastern portion to 37 inches in the extreme northwestern portion. Although the total annual rainfall varies little, the seasonal pattern of rainfall may vary widely from year to year. The variations in rainfall, temperature, vegetative cover, soil types, and snow storage capacity are factors leading to wide extremes in flow, from pool conditions to floods. These extreme variations in flow provide open river conditions and pool conditions for extended periods. For example, the flow at Cincinnati varied from 14,400 to 457,000 cfs in 1956 and from 6,750 to 474,000 cfs in 1957.

III. ANALYTICAL METHODS

(A) Physical-Chemical

The procedures followed in this study are the same as, or modifications of, those outlined in _Standard Methods for the Examination of Water, Sewage, and Industrial Wastes_, 10th Edition, 1955. These include:

Turbidity: Jackson candle method.
Light retention: Secchi disc (Welch, 1948).
Temperature: Whitney resistance thermometer. Standard centigrade thermometer.
Current flow: Cork float method (Welch, 1948).
Dissolved oxygen: Winkler method. Alsterberg and Rideal-Stewart modifications.
Free carbon dioxide: Interpolation from Moore's (1939) nomograph.
Alkalinity: Phenolphthalein and methyl-orange alkalinity indicator method.
Copper: Cuprethol method.
Iron: Pyridine test.
Manganese: Periodate method.
Phosphates: Stannous chloride method.
Nitrates: Brucine method.
pH: Electrometric and colorimetric methods.

A Bausch and Lomb spectronic-20 colorimeter was used for the nitrate, phosphate, iron, manganese, and copper determinations. All chemical measurements are expressed as milligrams per liter (mg/l).

(B) Biological

Plankton collections were obtained with a Clarke-Bumpus quantitative plankton sampler fitted with No. 20 and No. 25 mesh nets. Plankton analyses were made by both the strip-count and the field count with a Sedgwick-Rafter counting cell and a Whipple ocular disc. They are expressed volumetrically as cells per milliliter.

Samples were collected also with Petersen, orange-peel, and Eckman dredges and were sieved through a 100-mesh pan. The organisms were counted and identified to species wherever possible.

IV. OBSERVATIONS: SEVEN SELECTED REGIONS

(A) Physical-Chemical

More than 1600 physical and chemical determinations were made from samples collected during 1959, unless otherwise noted, in these regions. Many additional analyses were obtained from the Louisville Water Company, the United States Geological Survey, the U.S. Army Corps of Engineers, and the Ohio River Valley Water Sanitation Commission.

Figure 3 and Table 1 give graphic and tabular data pertinent to the seven regions of the river. In general, Regions 1, 2, and 3 were relatively stable in dissolved oxygen, high in acid, high in carbon dioxide, comparatively low in turbidity (as assessed from light penetration data), highly variable in temperature, and fairly stable in nitrate and phosphate contents.

Regions 4 through 7 had more stability in temperature, turbidity, higher alkalinity, higher pH, a wider range of dissolved oxygen, low carbon dioxide contents, and unstable nitrate and phosphate contents.

Region 1--One mile above confluence of Allegheny and Monongahela to mile 10. The 1959 steel strike in the Pittsburgh region was in progress during the period of sampling in this region and may be a contributory factor in the results. This section exhibited extremely low alkalinity and low pH values, conditions which are primarily the result of mine drainage. Several low dissolved oxygen values were also found in this region, but the Neville Island area between miles 5 and 10 contained the lowest concentrations. A reading of 1.7 mg/l was obtained from a sample taken on July 25 below the Pittsburgh sewage outlet. Five miles downstream the dissolved oxygen content was still low, 4.1 mg/l. The percentage saturation value of dissolved oxygen on July 25 was only 22 percent. However, a sample taken at mile 15 on this same day had an oxygen concentration of 6.7 mg/l.

Region 2--miles 15-31.7. In general, this region differed little from the preceding one. An oxygen value of 4.1 mg/l was taken near Montgomery Lock on June 27. On this same day, pH values of 3.6, 4.9, 5.1, and 6.4 occurred in samples at mile 29.7. The manganese content of Raccoon Creek on July 6 was 4.78 and 5.02 mg/l, and copper contents were 1.14 mg/l and 0.86 mg/l. The regions near Kupper's Outlet, Raccoon Creek, and Montgomery Lock indicate the need for additional study. Dissolved oxygen conditions were critical in these areas.

Region 3--miles 88-114. On the basis of analysis, this region appeared to have recovered somewhat. There were no indications of critical conditions from either the physical-chemical or the biological standpoint. Molluscan fauna began to appear in this region although many were badly eroded.

Alkalinity values remained rather low here except for the water coming from Fish Creek, which had contents of 94 mg/l. Values in the river proper ranged from 23 to 33 mg/l. The pH was slightly acid in places with readings of 6.6.

Region 4--miles 307.2-336.8. From all standpoints, this region was undoubtedly the most highly polluted. Extreme critical conditions were noted at mile 326. The pH readings at some of the industrial outlets in this region were between 2.8 and 3.2. Extremely high concentrations of copper, as much as 110.0 mg/l, have been found at this same site.

In the river pH readings were 6.0, 6.3, and 6.5, and the alkalinity values were 16, 28, and 31 mg/l. The carbon dioxide content ranged from 8.8 to 31.1 mg/l. Longitudinal series sampling for iron revealed initial content of 13.4 mg/l which was precipitated out or diluted to a safe condition of 0.14 mg/l ten miles downstream. In addition, the oxygen content was found to be 3.5 mg/l on July 15.

Figure 4 represents a series of 24 samples taken at mile 322 over a 24-hour period. This figure illustrates the normal pH-carbon dioxide-oxygen relationships and may serve to point out the danger of marginal oxygen contents. The carbon dioxide reached its highest peaks during the respiratory periods at night. At this time, phytoplankton populations made greater use of the dissolved oxygen and this accounted for the low levels during that period. During the night, pH readings reached their lowest values. During active photosynthetic periods in the daytime, however, the pH and dissolved oxygen values rose, while the carbon dioxide values declined. Inasmuch as lethal values are attained, therefore, more commonly during night hours, these conditions may not be disclosed by samples taken during daylight hours. This is especially true in hot weather, low-flow seasons, which are usually conducive to plankton blooms. Other oxygen values found in Region 4 are listed in Table 2.

Region 5--miles 445-484. Oxygen values in this region were low on June 11, 1959, at mile 483.2 (4.2 mg/l); on June 12 at mile 483.2 (4.1 mg/l); on June 13 at mile 483.4 (3.5 mg/l); on July 11 at mile 472.7 (4.7 mg/l); and on July 12 at mile 483.2 (5.7 mg/l). The latter value is not considered seriously low but could be classed as marginal. On all sampling dates the pH was slightly above 7. On July 11 at mile 472.7 the iron content was 1.10 mg/l. No other abnormalities were apparent in this region. The areas near Mill Creek (mile 472.7) and Addyston, Ohio (mile 483.4) were noticeably low in dissolved oxygen.

Region 6--miles 598-642.2. A fish kill occurred on July 10, 1959, near West Point, Kentucky. This kill was typical of several noted during the Aquatic-Life Resources study. Longitudinal series for dissolved oxygen were taken on July 6, July 10, and August 10. Of a total of 18 such samples taken between mile 603 and mile 630, only two had a dissolved oxygen content as great as 6.0 mg/l. One of these samples was taken at the mouth of Salt River at mile 629.8 and the other at mile 611. Other values ranged from 4.3 to 5.8 mg/l. Again, the result of these marginal or sub-marginal daytime oxygen values indicated a possibility of lethal conditions--"fish kills"--being produced at night. Other chemical and physical factors were in accord with what would be expected during the summer season.

Region 7--mile 973.6. The area around Mound City, Ill., appeared slightly deficient in dissolved oxygen content. Eight samples taken in this area in early afternoon on August 26 and 27 had contents ranging from 5.3 to 5.7 mg/l.

(B) Biological

1. Plankton

For this report, 210 plankton samples were analyzed, 90 of them quantitatively and 120 qualitatively. The plankton of the Ohio River is mainly autochthonous. A few limnoplankton and heleoplankton undoubtedly are contributed from flood-plain lakes and ponds, but apparently most of the plankton of these communities do not reach the river proper. The tributaries, especially the smaller ones, contribute little to the plankton community of the river. Therefore, the majority of the plankters must be developed on the mat algae in the shallow zones or in the backwaters and sloughs adjoining the main channel. By and large, the main constituents of the plankton communities are diatoms. The filamentous diatom *Melosira* was found in practically all samples and held a dominant position in all blooms. It is obvious from Table 3 that the species composition of the various regions was somewhat similar, differing mainly in quantities. This would suggest that the potamoplankton is eurytrophic.

Thirty-three species of rotifers belonging to 18 genera have been found in samples from the seven regions of the river. They constituted the dominant members of the zooplankton community, and, being browsers, made up a large portion of the second trophic level. *Keratella* and *Brachionus* were by far the most abundant in numbers of individuals and the most widely distributed, occurring in nearly all samples, as did two cladocerans *Bosmina* and *Chydorus*, and the copepod, *Cyclops*. Occasionally, a harpacticoid copepod, *Canthocamptus*, or even a *Hydra* may be contributed from the tychoplankter population of the river bed.

2. Phytoplankton Blooms

During the summer of 1959, several phytoplankton blooms appeared on the Ohio River. A bloom, in this report, is defined as a phytoplankton community having more than 500 cells per ml.

Region 1--One mile above confluence of Allegheny and Monongahela to mile 10. A plankton bloom recorded in Allegheny River mile 0.75 above the Point in Pittsburgh on July 25, 1959, consisted predominantly of *Melosira* and *Anacystis*, with an average of 771 cells per ml of water. Of five other plankton samples taken in this region, the greatest number of cells was 96 per ml. It would appear from the data available that the Allegheny River contributed more abundantly to the upper plankton community than did the Monongahela. The Monongahela on this same date had a plankton content of 41 cells per ml, which was represented by a nearly pure population of *Brachionus urceus*. The pH of the Monongahela on this date (July 25) was 5.2, whereas the Allegheny had a pH reading of 6.8.

The relatively low pH of the Monongahela probably accounts for the difference in the standing crop of plankton and for the fact that no plankton bloom was found below the confluence of the two rivers.

Region 2--miles 15-31.7. The plankton content of samples collected on June 27 and 28 and on July 31 ranged from 1.02 to 114.39 cells per ml, and the dominant species were *Melosira*, *Gonium*, and *Fragilaria*.

Region 3--miles 88-114. During July, 1959, the plankton counts in this section ranged from 112 to 118 cells per ml. The species composition was basically the same as that in Region 2.

Region 4--miles 307.2-336.8. Plankton samples taken on July 15 indicated the area above mile 326 contained 33 species with an average of 7,847 cells per ml. From mile 326 to 332 there were 21 species and 99.9 cells per ml, while below this area there were only 18 species and 191 cells per ml.

Bloom conditions were found in Region 4 at miles 307, 319.9, 322, 326, 327, and 328.1 during June and July. The number of cells ranged from 1,560 to 7,847 per ml. In the same period the Guyandot River samples had values of 24 and 99 cells per ml. Blooms were also present at mile 322 on August 16, 17, and 18; at mile 328.1 on August 29; and at mile 336.3 on August 19. The bloom conditions were characterized by the presence of *Melosira*, *Fragilaria*, *Synedra*, *Crucigenia*, *Dictyosphaerium*, and *Anacystis*.

Region 5--miles 445-484. Bloom conditions were present on June 14 at mile 465, Little Indian Creek, Painter Run Creek, and in the river at mile 443.8. These blooms were dominated by genera similar to those of Region 4.

Region 6--miles 598-642.2. Bloom conditions were present on July 7 and September 12, 19 and 25 in the vicinity of mile 600. Melosira, Anacystis, and Fragilaria were the predominant plankters in the samples showing bloom conditions.

Region 7--mile 973.6. Plankton analysis indicated a deficiency in numbers of species and individuals, and one sample contained no plankters.

3. Bottom Fauna

Bottom samples were limited to qualitative values only in the study. It might be noted only two or three specimens of Ephemerella were found during this study. The ephemeropteran populations are particularly sparse in the Ohio River in contrast to the large numbers present in the Mississippi River.

The rocky bottom communities were found in the main channel and consisted primarily of Hydra americana, Urnatella gracilis, Chironomus sp., Epistylis sp., Canthocamptus sp., and Vorticella sp. Pleurocera canaliculatum was fairly common on rocks at mile 598. The molluscan fauna was restricted mainly, however, to areas which did not receive the full force of the main channel current. This fauna consisted of the unionids Leptodea sp., Amblena costata, Quadrula quadrula, Quadrula metanevra, Quadrula pustulosa, Proptera alata, Lasmogonia sp., Fusconaia sp., and snails of the genera Pleurocera and Physa.

A well-developed molluscan fauna appeared to be present in Regions 4 through 6 (no data were available for Region 7) and probably indicated the pH-alkalinity values of the various regions. Figure 5, which represents a seven-year compilation of data pertinent to the pH and alkalinity of the entire river, indicates that the change in these two factors occurs near Region 4 and that conditions approach a normal level as one moves downstream.

Forty shells of Quadrula quadrula and 13 shells of Proptera alata collected at mile 484 were checked for growth and aging. Of the 53 specimens, 36 had only recently died, as was evident from the attached flesh, and 17 were badly eroded. Quadrula quadrula ranged in length from 18 to 37 millimeters, and *Proptera alata* from 50 to 68 mm. Best growth conditions apparently occurred in the years 1956-57. In age, the specimens ranged from three to seven years. Apparently Region 5 had active reproducing mollusca, and undoubtedly a fair molluscan population was present. This same generality was true of Region 6 and Region 7. Shells collected in Region 3 were eroded so badly that analyses were impossible. No living or recently living forms were found in this region.

The studies also revealed that the mud-bottom portions of outer reaches of the current contained large amounts of organic material with tubificids and a few specimens of *Tendipes* sp. This confirms past investigations in which a tremendous number of organisms were present in the mud-bottom region.

V. OBSERVATIONS: LOUISVILLE AREA

The region near the intake of the Louisville Water Company, mile 600, was selected as a site for more intensified limnological studies. The area was chosen because it contained waters which had little pollution, ample natural purification, and considerable dilution from tributary sources.

(A) Physical Environment

The nature of suspended material eventually is reflected in the bottom sediments. It was discovered during the spring of 1958 that the sediments in this section of the river varied widely in their composition. A large amount was present in the main channel of the river where depth exceeded 10 meters. The particles passed through a 20-mesh sieve but were retained in a 40-mesh sieve. This material was also mixed with clay and a tan organic ooze. Deposits of clay and of fine-grained organic ooze often lay adjacent to the sandier sections with dead leaves covering the bottom during the autumn. Rocks were frequently found scattered over the river floor.

It has been observed in this section of the river that during a "washout period" such as that which occurred on August 12, 1958, the river had a lower oxygen content and transparency level than normal. To obtain a better understanding, studies were made on the rate of settling of suspended material. It was determined that the suspended material settled out during the period of July 31 to August 10, at the rate of 0.15 mg/l per day. The average dry weight of these suspended solids for this period was 0.2759 g/l.

Variation in turbidity is demonstrated in Figures 6 and 7. Turbidity values ranged from 5 mg/l on January 1 to 2,500 mg/l on January 22 and 23. Associated with these values was a minimum flow of 36,400 cfs on January 10 to a maximum 516,000 cfs on January 26. The maximum rate of river rise was 0.63 feet per hour on January 21, while the next highest rate was 0.28 feet per hour on January 9.

During the spring of 1959, an intensive analysis was made of seasonal variation in flow at Louisville, mile 607. The months of April, May and June saw a transition from the previous winter flooding conditions. April began with a flow of 135,000 cfs. The volume of flow increased steadily to a maximum for the month of 272,000 cfs on April 17, and then fell rapidly to a minimum of 105,000 cfs on April 26. By the end of April, the volume of flow had increased to 123,000 cfs. Fluctuation in the river level occurred on 27 of the 30 days. Increasing rates of change per hour occurred on 15 days, declining rates of change on 12 days, and stable conditions on 3 days. The maximum rate of rise was 0.11 feet per hour on April 15, whereas the maximum fall in water level was 0.15 on April 19 and 20. During April, on only 10 days did volumes of flow fall below 150,000 cfs, and none fell below 100,000 cfs.

On 23 days in May the volume of flow was less than 150,000 cfs. On 14 days the flow was below 100,000 cfs, and on May 29, the volume of flow fell to a minimum for the month of 43,000 cfs. Stable water levels were less evident during May than in April. On only one day, May 31, did the river remain stable. The maximum rise in water level occurred on May 16 and 17, when the rate of change per hour was 0.11 feet. The maximum fall occurred on May 11 and May 12, when the rate of change per hour was 0.09 feet.

The flow in June did not exceed 150,000 cfs. There were 29 days in which it was below 100,000 cfs, 20 days below 50,000 cfs, and 5 days below 25,000 cfs. Stability increased during this month, with no change in water levels on 15 days. The river rose on 12 days with a maximum rate of change per hour of 0.16 feet on June 5, and fell on 9 days with a maximum rate of change per hour of 0.26 feet. The lowest volume of flow for this period was recorded on June 21, at 23,000 cfs. The most dramatic change occurred when the flow of 114,000 cfs on June 27 fell rapidly to 40,000 cfs within three days.

The significant points of the spring flow data analyses are that the volume of flow gradually decreased to a nine-year low of 16,800 cfs on June 21, with an increase in stability during this period. The results of these stable conditions are potential plankton blooms with their associated taste and odor problems; much decomposition accelerated by the seasonal temperature; fish kills in the region of insufficient oxygen; accumulation of industrial waste and municipal sewage with lack of normal dilution activities. In effect, low volume of flow and an accompanying high temperature are in general deleterious. These conditions appeared earlier in 1959 than usual.

Temperature profiles made during the period from October 1 to December 31, 1957, from surface to the bottom (13 meters) seldom differed more than 0.1°C.

(B) Chemical Environment

There was close similarity between samples of water taken at the surface and those taken from near the bottom (13 meters) in the mid-channel area, particularly in dissolved oxygen, free carbon dioxide, pH, and total alkalinity. This similarity would tend to suggest that there was little stratification in this section of the river during the period October 1 to December 31, 1957, in which these determinations were made. Dissolved oxygen at both the bottom and the surface was about 50% of saturation during the autumn of 1957. On October 8, 1958, dissolved oxygen at the surface measured 120% saturation and on November 21, the minimum record of 60%. The normal concentration of dissolved oxygen in the water at this station was 85 to 95% saturation. One of the lowest percentage saturations for dissolved oxygen measured in Region 6 occurred in the river below the outlet of Beargrass Creek. On March 16, 1959, the dissolved oxygen content at this point was only 33%.

Six oxygen samples collected from the surface of the river on June 8, 1958, in a 22-mile stretch of river below Louisville (mile 607 to mile 629.9) showed the following results:

Longitudinal Series Dissolved Oxygen in Milligrams per Liter

mile 607	4.3
mile 611	5.0
mile 616	4.3
mile 621	4.8
mile 627	4.7
mile 629.9	5.3

Samples taken in this region on June 4 and June 9 showed concentrations of 4.7 and 5.4 mg/l dissolved oxygen at miles 611 and 629.9, respectively, making it evident that no significant recovery took place over the 22-mile stretch.

The pH values from this section of the river generally ranged from 7.2 to 7.6. An exception occurred on October 8, 1958, when the pH measured 8.4 at the surface and 7.9 at the bottom.

In this section of the river phenolphthalein alkalinity values were rare. Thus the total alkalinity may be attributed almost entirely to the bicarbonates. The low values of alkalinity usually occurred in the spring during high water, while high alkalinity values usually appeared in the fall with low water. On April 11, 1958, the total alkalinity was 41 mg/l, while on September 20, 1958, it was 105 mg/l.

(C) Biological Environment

1. Zooplankton

The following species of zooplankton were abundant during autumnal and early hibernal 1957 and 1958: Keratella cochlearis, Keratella vulgara, Platyias patulus, and Bosmina longirostris. Brachionus calyciflorus, Brachionus quadridentata, Filinia longiseta, and Colurella sp. were found in lesser amounts. The protozoans Difflugia sp., Vorticella microstoma, and Vorticella campanula were also common during this period.

Table 4 lists the zooplankton organisms collected from October 4 to December 17, 1958. On March 16, 1959, a large number of Difflugia urceolata and Codonella cratera were collected on the Kentucky side of the Ohio River at mile 602.1, with a Clarke-Bumpus net. On March 30, 1959, at mile 602.1, the major zooplankter in the collection was Vorticella. Other species found in this sample were Cyclops, Brachionus, Simocephalus, Scaridium, napulii stages, and a ploimate rotifer.

2. Phytoplankton and Other Algae

From June to October 1958, no large algal blooms occurred on the Ohio River at Louisville. During the last weeks of September diatoms appeared to increase in number. The Louisville Water Company reported tastes and odors labeled "algae" in the raw river water at the following times:

1957		1958	
June	- 23 days	June	- 2 days
July	- 20 days	July	- 12 days
Aug.	- 30 days	Aug.	- 0 days
Sept.	- 30 days	Sept.	- 19 days

The unusually low population of algae during the summer of 1958 may be attributed to the extremely large volume of flow and high turbidity values. In the September collection, Melosira and Synedra were quite abundant. Table 5 shows phytoplankton collected during the summer of 1958.

In the fall of 1958, plankton algae were collected in the area between McAlpine Lock and Twelve Mile Island. Because of unusual summer water conditions, the blue-green algae did not develop to the magnitude they otherwise would have reached. Anacystis was abundant during the end of September in the river and particularly at the mouths of tributary streams such as Harrod's Creek. Oscillatoria was abundant in polluted areas below McAlpine Dam.

The filamentous species of *Melosira* were the most abundant diatoms, followed by *Synedra* and *Asterionella*. The order Chlorococcales of the green algae was represented by many forms, as seen in Table 6. Various species of attached, nonplanktonic algae were found growing on all types of submerged objects, such as rocks and sticks. Among these forms were *Cladophora*, *Oedogonium*, *Stigeoclonium*, and *Schizomeria*. In the polluted waters near Beargrass Creek and in the municipal harbor, *Oscillatoria*, *Phormidium*, and *Lyngbya* were abundant.

Table 7 contains the taste and odor data from October, November, and December, 1958, as reported by the Louisville Water Company. An interpretation of these taste and odors data may be found in Table 8.

The dominant phytoplankter during the spring of 1959 was *Melosira*, which represented 60 to 100 percent of the organisms in a series of eight plankton samples. The algae occurring during the summer of 1959 are reported in chapter IV of this section, under Region 6.

During October, 1959, a heavy algal bloom of *Anacystis* appeared in the river. On October 6, a single sample was collected and photosynthetic rates were determined on six aliquots by means of associated pH changes. The obtained values were all negative, indicating total absence of photosynthesis, and although the blue-greens in the river appeared to be in a healthy condition, the organisms were actually "sick, dying, or dead." Much of the bloom broke up by October 25, with *Anacystis* forming large masses of the aggregated material. These decomposing blue-greens were undoubtedly the major contributory factor to the taste of the water during the latter part of October.

3. Bottom Fauna

The distribution of benthic organisms is related to the type of bottom. In the sandy and clay bottom of the midchannel the chironomid larvae, *Tendipes decorus*, were abundant. This organism was the major food item of many of the smaller fishes found in this region. Stomachs of young channel catfish, young freshwater drum, and silver chub contained large numbers of these larvae. No specimens of *Tendipes decorus* were found during winter sampling. The midge larva, *Procladius*, was found in deep sediment. The dipterous larva, *Chaoborus*, rarely appeared in the samples. Other organisms of this particular bottom type included tubificid oligochaetes, several species of *Pisidium* and a few unionid clams.

Rocky bottoms contained a strikingly different fauna, comprised predominantly of triclad flatworms, leeches, crayfish, aeschnid dragonfly naiads, and other aquatic insect larvae. The snail *Pleurocera canaliculatum* was found only on the rocky substrata. The sphaeriid clams, especially Pisidium, and the snails Somatogyrus subglobosus and Viviparus contectoives occurred here.

An examination of the unionid fauna of this section of the river showed Leptodea fragilis to be the dominant species with Proptera alata a subordinate representative. Quadrula pustulosa and Amblena were occasionally found.

Large populations of Hydra americana were obtained at a depth of five meters at mile 604 during the summer of 1958. Also found here and at mile 619 was the bryozoid, Urnatella gracilis.

Samples of different types of bottoms and from various depths revealed fewer organisms on bottoms of sand or sand and silt than on bottoms of silt alone. For example, on March 30, 1959, a sample from a bottom of sand and silt at a depth of 2.6 meters along the Kentucky shore above mile 602.1, contained 129 organisms per square meter. Another sample collected on the same date from a silt bottom at a depth of 10 meters, along the Indiana shore at mile 602.1, yielded 73,100 tubificids per square meter.

4. Bacteria of the Ohio River Sediments

During the winter of 1959-60, three stations, (1) 20 feet from the Kentucky bank, (2) mid-river, and (3) 20 feet from the Indiana line, were established at mile 599.1 on the Ohio River. The depths of these sites were 20, 35, and 20 feet, respectively. Samples of sediments were collected from each site four times during the period October 2, 1959 to January 2, 1960, with an Eckman dredge. All the sediments were of a clay nature. The bacterial populations of these sediments were studied for both total bacterial counts and coliform counts (Standard Methods for the Examination of Dairy Products, 1953). Table 9 gives the results of this study.

(D) Observations on Contiguous Pools

During the fall of 1958, two stations were established, one above and one below McAlpine Dam. Station 1, above the dam, extended from the mouth of Harrod's Creek at mile 596 to the Louisville Municipal Harbor at mile 602. Station 2 extended from the dam at mile 607.4 to mile 618. Station 1 as an area may best be described as a pool, having depths near Cox Park greater than 17 meters. The bottom contained much organic material and large amounts of silt. Terrestrial succession extended from the banks toward the channel current. Sampling emphasis was placed on the rocky and sandy bottom portions of this station. Bryozoans were abundant in this area. Not only were Urnatella gracilis and Paludicella articulata present, but also the statoblasts, Lophopodella carteri and Plumatella repens. The snail, Pleurocera, and Hydra americana were also abundant. Keratella cochlearis, Brachionus calyciflorus, Polyarthra trigla, Cyclops, and Bosmina longirostris were the characteristic plankters. Plankton was more abundant at Station 1 than at Station 2. Linear plankton samples, taken at one-mile intervals on two different occasions, showed no difference in species composition (Table 4).

Station 2 included most of the area which receives wastes from the city of Louisville. Apart from the absence of statoblasts and the presence of only the shells of Pleurocera, the bottom and plankton fauna was similar to that of Station 1.

VI. DISCUSSION:

THE PHYSICAL-CHEMICAL-BIOLOGICAL NATURE OF THE OHIO RIVER

(A) Physical-Chemical Characteristics

Dissolved Oxygen. The regions of the Ohio River directly below Pittsburgh, Pa. (Region 1), Cincinnati, Ohio (Region 5), and Louisville, Ky. (Region 6), represented areas of decreased oxygen content. The dissolved oxygen levels were especially significant in that all the samples represented daylight conditions. With daytime concentrations such as these, during low flow and high temperature periods one can expect drastic reduction in the oxygen contents during the night as a result of phytoplankton metabolism. In effect, the desired 5 ppm value for 16 out of the 24 hours is certain not to be met under such conditions.

pH Values. Samples collected from the Pittsburgh and Wheeling (Region 3) regions had pH values consistently on the acid side, some as low as 3.6, which are obviously harmful to aquatic life of this section.

Except for heavy discharge areas, the remainder of the samples from other regions revealed pH values ranging from 7.1 to 7.7.

Iron. All the regions except the Louisville region and Region 7 contained excessive total iron concentrations. Louisville samples contained iron ranging from 0.14 to 0.55 mg/l and the Pittsburgh region samples ranged from 0.10 to 16.76 mg/l. The Wheeling region had areas where a great deal of iron had encrusted the bottom of the stream as well as rocks on the shore. Many submerged tree limbs and mollusc shells were covered with these deposits at mile 108.1 at Little Captina Creek. Iron contents of the Ashland region (Region 4) ranged from 2.30 to more than 8.5 mg/l. At Cincinnati the iron content ranged from 0.14 up to 2.30 mg/l.

At the pH values present in the areas containing excessive iron deposits, it is probable that the iron was precipitated out in the ferric condition. One of the most noteworthy effects of these excessive deposits was the virtual absence of bottom fauna. Other significant effects of iron are the clogging of mechanisms such as the gills, respiratory and feeding apparatuses of aquatic animals, and the destruction of many aquatic plants.

Manganese. Excessive amounts of manganese were found at mile 29.7, Raccoon Creek (4.28 mg/l); mile 29.8, Four Mile Run (5.02 mg/l); mile 108.1, Little Captina Creek (4.28 mg/l); and at mile 470.5, mouth of Licking River (1.53 mg/l).

Copper. Copper values ranged from 0 to 110.00 mg/l. The latter value was from an industrial waste discharge sample taken at mile 326. A sample taken at Little Captina Creek, mile 108.1, contained 6.00 mg/l copper.

Phosphate. Phosphate contents in the Ohio River ranged from 0.2 to 1.5 mg/l. The 1.5 value was obtained from water at the mouth of Raccoon Creek at mile 29.7 on June 27. A similar value was obtained from a sample taken at mile 480.6 at the mouth of Rapid Run below Cincinnati on June 11.

Alkalinity. Alkalinity values during the summer of 1959 ranged from 22 to 95 mg/l as calcium carbonate. Although the total alkalinity of the Ohio River proper did not exceed 95 mg/l, several tributaries did have higher concentrations.

The regions above Cincinnati had low alkalinities. The values for the Pittsburgh, Wheeling, and Ashland regions, respectively, ranged from 22 to 45, 29 to 37, and 27 to 45 mg/l. These values may present chemical barriers to the development of certain aquatic forms and to the upstream or downstream migration of others. In the Cincinnati and Louisville regions, alkalinity values ranged from 53 to 73 mg/l and 31 to 95 mg/l, respectively. The tributaries around and below Cincinnati undoubtedly accounted for the rise in alkalinity values.

Turbidity and Light Penetration. In general, turbidity did not impose limitations on aquatic life. For example, turbidity values during the summer of 1959 ranged from less than 25 to 250 ppm.

Secchi disc values likewise indicated no imposition on aquatic life. There were no important differences between minimum readings from the various sections. All regions had minimum values below ten inches. Upper values, however, showed some difference. Only the Louisville region did not have values of at least 25 inches.

Temperature. There was no significant difference in the water temperature in the various regions of the Ohio River during the summer of 1959. The water temperatures may have had the effect of removing some of the tributary forms and, as mentioned earlier, of causing plankton blooms and accelerating decomposition and respiration.

(B) Biological Conditions

The plankton of the Ohio River is rich and varied. Little correlation, however, has been established between comparative numbers and physical or chemical factors. Large quantities of phosphates or nitrates generally contribute to the initiation of plankton blooms, although no direct relationship has been demonstrated during the study.

The 1957-58 plankton population of the Ohio River was indicated by minimum and maximum values of 320 to 24,940 organisms per ml with a mean of 2,600 (U.S. Public Health Service, 1958). Many areas of the Ohio, instead of having a paucity of plankton, are unfortunately blessed, at times, with plankton blooms. During the summer of 1959, plankton blooms were recorded for Region 1 (an unusual incident), Region 4, Region 5, and Region 6.

The bottom fauna of these regions varies directly with the type of substratum and the degree of pollution in the river. Areas below Cincinnati and Louisville, where considerable organic matter accumulates on the bottom, have a high population of Chironomids and other low-oxygen-tolerant invertebrates, whereas unpolluted areas contain caddis flies, stone flies, and large beds of clams. At Leavenworth, Indiana, "shellers" have collected from the river 1 to 1.5 tons of mussels per week, which they sell for about $50 a ton (Hubbard, 1953).

VII. CONCLUSIONS

A river cannot be considered homogeneous or a continuum in any but a physical sense. The implications in this realization are many: seasonal, temporal, and spatial. The dynamics are especially complicated when we consider the direct influences imposed by man. While ample evidence exists, both quantitative and qualitative, to the effect that certain regions of the river are now, and have been, polluted, it is necessary to be cautious in using some of these particulars to assess generalities.

On the basis of sampling, analysis, review of the literature and general observations on the Ohio River during the Aquatic-Life Resources study, it is apparent that the river is not a "clean stream." Some sections of it, such as that located above the city of Louisville, are relatively clean. This section serves as a base with which to compare other areas in the river which have not had the benefit of tributary waters subject to little pollution nor ample time for self-purification.

The greatest threat to a restoration of the Ohio River stems from inevitable increases in human population and in industry in the Ohio River valley. The disoperative factors imposed by a technological society upon its environment, and in this case upon the Ohio River, are not wholly subject to remedy. These influences are displayed in many ways, as in the length of recovery zones below cities. The length of the recovery zone below Louisville is presently about 25 miles; its length in the future will be an index of the efficiency and degree to which sewage and industrial waste treatment and other clean water practices are developed and employed.

AQUATIC-LIFE RESOURCES

OF THE OHIO RIVER

SECTION III

THE FISH POPULATION

OF THE OHIO RIVER

by Louis A. Krumholz, James R. Charles, and W. L. Minckley

I. INTRODUCTION

Although the broad objective of the Aquatic-Life Resources project was an appraisal of the suitability of the Ohio River for the maintenance of aquatic life, a major effort during the entire study consisted in determining the species composition, the distribution, and the relative abundance of the different kinds of fishes inhabiting the river. The fish population study extended from May 27, 1957 through the end of 1959 and was a cooperative enterprise between the Department of Biology of the University of Louisville and the Division of Fisheries, Kentucky Department of Fish and Wildlife Resources. Each group maintained a crew in the field during each year of the study to collect fishes from the various waters that are part of or tributary to the Ohio River. The field work for the University of Louisville was under the direction of Dr. Krumholz from May, 1957 until the spring of 1959, when he was replaced by Mr. Minckley for the remainder of the study. During the entire period, the field work for the Kentucky Department of Fish and Wildlife Resources was under the supervision of Mr. James Charles.

The fish population was sampled at various places throughout the entire length of the river at all seasons of the year by treating with rotenone the various lock chambers, stream mouths, backwaters, and other such areas as seemed desirable; by seining; by netting with hoopnets, trammel nets, and gill nets; by electric shocker; by otter trawl in various locations to sample the deep-water fishes of the river; and in some instances by hook and line. All together, 341 collections were made during the entire study period. In each collection, the fishes were sorted to species, counted, and weighed. In some instances, representative samples were preserved and later catalogued and placed in the fish collection at the University of Louisville. During the study a total of 130 kinds of fishes were taken, ranging in size from some of the very small minnows and darters to some of the very large catfishes and deep-bodied suckers. The total number of individual fish collected was 741,438 and the total weight of those fish was 32,679 lbs. Of the 341 collections, the crew from the Kentucky Department of Fish and Wildlife Resources made collections only from the Kentucky waters of the river, whereas those by the University of Louisville crew were taken over the entire length of the stream.

II. MATERIALS AND METHODS

About two-thirds (225) of the 341 collections were taken with emulsifiable rotenone (Table 11). The rotenone was dispersed into the water through a K-B boat bailer in the wake of an outboard motor. In all instances an attempt was made to secure a rotenone concentration of at least one part per million. The samples taken with rotenone were subdivided into four principal groups: (1) lock chambers in the main stream of the Ohio River; (2) the mouths of tributaries to the Ohio River; (3) lock chambers in streams tributary to the Ohio River; and (4) backwaters, mostly behind esplanades in the lock-and-dam areas. In each location, the rotenone was dispersed over the surface of the water in a crisscross manner to cover the entire area. As soon as the fish began rising to the surface they were picked up with dipnets, placed in tubs in the boat, and taken to shore for sorting. Every effort was made to recover all fishes in the areas sampled.

Of the remaining 116 samples taken, more were taken by hoopnets than by any other method, and the hoopnetting was followed in order by samples taken by seining, by the electric shocker, by the otter trawl, by gill nets, by trammel nets, and by pole and line, as indicated in Table 11 and Figure 8.

In the collection made by hoopnets, the nets used in these studies were three- or four-foot hoopnets with a bar mesh of two inches. All nets were double-throated. The nets were fished unbaited, usually without wings or leads, in current, and in water ranging from 3 to 25 feet deep. In all instances the sets were left in place at least 12 hours, but all catches were recorded on a 24-hour basis.

Seining was done with fine-mesh minnow seines or with 30-foot or 60-foot nylon bag seines. Each collection consisted of the catches from about 5 to 30 hauls. Most seining was done near the shores in shallow water along the heads of islands and on sand bars that occur in various places throughout the length of the Ohio River.

Electric shocking was done by using a gasoline-driven generator with an output of 115 volts, 600 watts, A.C., and equipped with boom-type electrodes placed in the water just ahead of the slowly moving boat. There were four such electrodes, each 8 feet long.

Trawling was done by pulling an otter trawl with a 10-foot or 16-foot bag, of the type used in the Gulf of Mexico for shrimp fishing, behind a cruiser or one of the smaller outboard-powered aluminum boats. Each collection consisted of from two to eight hauls that lasted from 5 to 10 minutes each. The hauls were made either upstream or downstream at a water speed of 1 to 3 knots.

Gill nets and trammel nets were either drifted with the current or set obliquely from shore according to the effectiveness of the method and the types of fishes sought.

A rough estimate of the standing crop of fishes in the Ohio River was made by determining the area of the various lock chambers treated with rotenone, calculating the total weight of the fishes taken from them, and then estimating the standing crop per acre. Of course it is to be understood that this is merely an estimate and not an absolute figure. However, the average total weight of all fishes taken from all lock chambers over the entire length of the Ohio River may be a fair representation of the standing crop of fishes taken in any particular area.

The percentage distribution of the number of collections taken during each of the three years, together with the percentage for each of the different methods, is shown in Figure 8. Nearly half the collections were taken during 1959, 30 per cent during 1958, and about 20 per cent during 1957. However, the greatest number (417,302) and the greatest weight (14,592 lbs.) of fishes were taken during 1958, when nearly all collecting was done with rotenone. The 225 rotenone collections included 124 in main stream lock chambers, 78 in the mouths of tributaries to the main stream, 12 in lock chambers of tributary streams, 8 in backwaters of the main stream, and 3 in the mouths of tributaries to the Allegheny and Monongahela Rivers above Pittsburgh. Thus, well over half of all the rotenone samples were taken from the lock chambers and in mouths of streams tributary to the Ohio River itself. During 1957 and 1958 nearly all the collecting was done with rotenone, whereas during 1959, when nearly half the samples were taken, relatively greater stress was placed on the use of other, less time-consuming gear such as hoopnets and electric shocker.

It is well known that all types of collecting gear used here are more or less selective for certain species and sizes of fishes. For instance, the size of the mesh in hoopnets, trammel nets, and gill nets will restrict the size of fishes that can be taken by those nets. With the otter trawl, the size is restricted by the movement of the boat and the movement of the net across the bottom, and also by the size of the meshes in the net. Similarly, with seines, most of the collecting was done with small-mesh seines in rather shallow waters where very few large fishes were present. On the whole, sampling by rotenone is much less selective than most other methods, although there is some difference in the susceptibility of different fishes to this chemical. All fishes, so far as we know, are susceptible to rotenone and will be killed by it if the concentration is high enough and they are exposed long enough. However, some fishes are much more hardy than others. For instance, the goldfish (Carassius auratus) and the bullheads (Ictalurus spp.) are much more resistant to the effects of rotenone than are the gizzard shad (Dorosoma cepedianum) and some of the minnows. Also, some of the other catfishes and the gars (Lepisosteus spp.), the bowfin (Amia calva), and the eel (Anguilla rostrata) can apparently withstand higher concentrations of the chemical for longer periods of time than other fishes. Still other fishes, such as the skipjack herring (Alosa chrysochloris), are quickly killed, but if they are not picked up promptly they will sink to the bottom and can not be recovered. Furthermore, the effectiveness of rotenone as a fish toxicant is reduced as the temperature decreases, particularly at temperatures below about 45 degrees Fahrenheit. At such temperatures the reaction to the rotenone is quite slow, presumably because the metabolism of the fishes has been reduced in response to the cooler environment. By contrast, when the temperature was above 70 degrees Fahrenheit, the reaction of the fishes to rotenone was about as good as could be expected. In addition to the physiological responses related to temperature of the environment, there are anatomical differences among fishes which restrict them to certain parts of the river. For instance, none of the darters have air bladders, and as a result, when they come to the surface of the water, if they are not picked up immediately, they have virtually no buoyancy and will sink rapidly to the bottom.

III. THE FISH COLLECTIONS

A. General Species Composition

The relative abundance of fishes in the Ohio River, based on the data for all fishes collected during the study, may be considered in the following ways: (1) by the number of individuals of each species, (2) by the total weight of the individuals of each species, and (3) by the numbers and weights for each species taken each year.

If the arbitrary figure of 1,000 individuals is used for separating the numerically abundant species from those not so abundant, there are 21 species, as listed in Table 12, in this category. Similarly, if the arbitrary figure of 100 lbs. is used for separating the more abundant from the less abundant species on the basis of weight, there are again 21 species in this category as listed in Table 12. However, the species for the two categories are not the same; there are six species whose total number was less than 1,000 but whose total weight was greater than 100 lbs., and there were six species which had a total number greater than 1,000 but whose total weight was less than 100 lbs. If only these 27 species which comprise only slightly more than one-fifth of all species taken are considered, they make up about 97.5 per cent of the total number and about 96 per cent of the total weight of all fishes taken during the entire study.

Of the numerically most abundant species, the emerald shiner (*Notropis atherinoides*) was taken in far greater numbers than any other species and made up nearly 58 per cent of all fishes taken during the study, and this minnow, together with the other small minnows, made up more than two-thirds of the total numbers taken. Of the most abundant fishes by weight, the gizzard shad made up nearly 45 per cent of the total weight of all fishes and was followed in order by the carp (*Cyprinus carpio*), the channel catfish (*Ictalurus punctatus*), and the freshwater drum (*Aplodinotus grunniens*). These four species made up slightly more than 75 per cent of the total weight of all fishes, and the three food fishes--the carp, the channel catfish, and the freshwater drum--made up a little more than 30 per cent.

The relative abundance of the ten most abundant species in the collections by both number and weight is shown graphically in Figure 9. Only six of these species are among the ten most abundant species in number as well as in weight.

On an annual basis (Table 13, Figs. 10, 11, and 12), more fish were taken during 1958, both in numbers and in total weight, than in either of the other two years. In each of the three years, however, the emerald shiner and the gizzard shad were the two most abundant fishes numerically, and the gizzard shad was the most abundant fish by weight during the first two years, while the carp was the most abundant fish by weight during the third year. The apparent reason for the relative scarcity of the gizzard shad in the 1959 collections was that much of the sampling was done with other methods than rotenone, and these other methods are much more selective for other species.

All fishes of which more than 500 individuals or more than 100 lbs. total weight were taken during any one year of the study period are listed in Table 14. From these data, it is readily apparent that there was considerable fluctuation in abundance, both in number and in weight, of these 26 different species from one year to the next; some fishes were taken much more frequently one year than another. Of those 26 species, only 7, the gizzard shad, the carp, the emerald shiner, the blue catfish (Ictalurus furcatus), the black bullhead (Ictalurus melas), the channel catfish, and the freshwater drum contributed more than 500 individuals and more than 100 lbs. to the total catch each of the three years. Much of this variation may have been traceable to the areas in which the collections were taken. For instance, in 1957, the troutperch (Percopsis omiscomaycus), the tenth most numerically abundant fish taken, was represented by 997 individuals. Its frequency that year resulted from collections taken in the Allegheny River above Pittsburgh, where the troutperch is relatively abundant. No collections were made in that area during 1958 or 1959.

However, the threadfin shad (Dorosoma petenense), the fifth most numerically abundant fish taken in 1957 and the eleventh in 1959, was not taken in large enough numbers to be included in the group contributing more than 500 individuals to the collections during 1958. Here, such a discrepancy is difficult to trace because collections were being made in the same manner, over relatively the same period of time. Also, hybrids between the gizzard shad and the threadfin shad were collected (Minckley and Krumholz, 1960) from the Ohio River below Louisville during each of the three years of the survey.

B. Geographic Distribution

To analyze the data for differences in geographic distribution, the river was divided into 100-mile sections with Pittsburgh (mile 0) as the starting point. Thus Section 1 refers to the first 100 miles below Pittsburgh (mile 0 to mile 100), Section 2 to miles 100 to 200 and so on with miles 900 to 981 comprising Section 10. The area above Pittsburgh, in the lower portions of the Allegheny and Monongahela Rivers and their tributaries only, is included in Section 0 (Fig. 13).

The mimic shiner (Notropis volucellus) was numerically the most abundant species in the collections above Pittsburgh. In the Ohio River proper, the emerald shiner was most abundant in Sections 1, 2, 3, 4, and 7; the channel catfish in Section 5; the freshwater drum in Sections 6 and 9; and the gizzard shad in Sections 8 and 10. The percentage composition of the total catch of the ten most abundant fishes and weight is shown for each section of the river in Figures 14 through 24.

Section 0 (above Pittsburgh): Nearly 90 per cent of all fishes taken were mimic shiners and emerald shiners, and these two species, together with the troutperch and the rosyface shiner (Notropis rubellus), contributed more than 96 per cent of the total numbers of fishes taken. However, in total weight, the carp contributed 34.3 per cent, the white sucker (Catostomus commersoni) 20.2 per cent, the emerald shiner 10.4 per cent, the golden redhorse (Moxostoma erythrurum) 5.3 per cent, and the mimic shiner 4.9 per cent of the total catch.

Section 1 (miles 0 to 100): The emerald shiner constituted nearly 85 per cent of the total number of fish taken, followed by the black bullhead (6.1 per cent), the sand shiner (Notropis stramineus) (2.5 per cent), the mimic shiner (1.2 per cent), and the golden shiner (Notemigonus crysoleucas) (0.8 per cent), for a total of 95.5 per cent. The black bullhead also contributed nearly a third of the total weight (32.2 per cent), the emerald shiner 16.7 per cent, the carp 11.6 per cent, the skipjack herring 10.6 per cent, and the gizzard shad 8.9 per cent, for a total of 80 per cent.

Section 2 (miles 100-200): The emerald shiner was the most abundant fish, contributing 85.6 per cent of the total number of fish taken, followed by the mimic shiner with 9.9 per cent; the two species contributed more than 95 per cent of the total catch. The channel catfish, the black bullhead, and the sand shiner followed in that order. The carp comprised nearly half (49.8 per cent) the total weight, followed by the emerald shiner (21.4 per cent), the channel catfish (10.9 per cent), the black bullhead (3.1 per cent), and the gizzard shad (2.5 per cent), for a total of 87.7 per cent.

Section 3 (miles 200-300): The emerald shiner, again the most abundant fish, made up 75.8 per cent, followed by the mimic shiner (13.7 per cent), the channel catfish (3.4 per cent), the gizzard shad (1.5 per cent), and a newcomer to the first five, the silver chub (Hybopsis storeriana) (1.3 per cent), for a total of 95.7 per cent. Among the first five in weight, the gizzard shad contributed 26.6 per cent, the channel catfish 14.5 per cent, the emerald shiner 12.0 per cent, the carp 11.4 per cent, and the skipjack herring 6.1 per cent, their combined weight being 70.6 per cent of the total.

Section 4 (miles 300-400): Although the relative abundance of the emerald shiner was lower than in the previous sections, it was numerically the most abundant species (31.4 per cent), and was followed by the mimic shiner (15.2

per cent), the channel catfish (13.1 per cent), the gizzard shad (10.0 per cent), and the freshwater drum (3.9 per cent), and these five species made up 73.6 per cent of the total catch. Here it is noteworthy that this is the uppermost section of the river in which the freshwater drum was among the five numerically most abundant fishes in the collections. In weight, the carp contributed 21.4 per cent, followed by the channel catfish (21.3 per cent), the gizzard shad (13.0 per cent), the freshwater drum (9.7 per cent), and the smallmouth buffalo (Ictiobus bubalus) (6.5 per cent), for a total of 71.9 per cent.

Section 5 (miles 400-500): Here, the most abundant fish was the channel catfish, which contributed 26.2 per cent of the total numbers caught. The gizzard shad contributed 22.7 per cent, the emerald shiner 16.8 per cent, the freshwater drum 8.8 per cent, and the silver chub 5.0 per cent, for a total of 79.5 per cent. Here for the first time the two most numerically abundant fishes were also the two most abundant by weight in the collections. Of the total weight, the channel catfish contributed 46.6 per cent, the gizzard shad 22.6 per cent, the freshwater drum 8.0 per cent, the carp 8.0 per cent, and the flathead catfish (Pylodictis olivaris) 4.7 per cent; these five species contributed 89.9 per cent of the total weight of fish caught. This is the first instance in which the percentage of the total weight contributed by the first five species was greater than the percentage of the total numbers contributed by the five most numerous species, and is an indication that the fishes taken in this area were relatively larger than those caught upstream.

Section 6 (miles 500-600): The freshwater drum was numerically the most abundant species and constituted 41.3 per cent of the total catch. It was followed in order by the silver chub (16.0 per cent), the emerald shiner (13.1 per cent), the channel catfish (7.3 per cent), and the gizzard shad (4.7 per cent), for a total of 82.4 per cent. The channel catfish was the most abundant fish by weight, contributing 21.4 per cent of the total, followed by gizzard shad (16.3 per cent), the freshwater drum (11.8 per cent), the carp (10.4 per cent), and the spotted sucker (Minytrema melanops), which contributed 9.1 per cent, for a cumulative total of 69.0 per cent. The great quantity of spotted suckers in this area occurred in several collections from stream mouths, principally in Harrod's Creek.

Section 7 (miles 600-700): Of the 34 collections in this section, 28 were made in the auxiliary chamber of McAlpine Lock and Dam, which because of its proximity to the University of Louisville was chosen for repeated sampling. The results of this intensive study are discussed later in this report.

Here again, the emerald shiner was numerically the most abundant species and contributed 48.4 per cent of the total catch. It was followed in order by the gizzard shad (34.3 per cent), the freshwater drum (7.3 per cent), the silver chub (2.2 per cent), and the threadfin shad (1.5 per cent), for a total of 93.7 per cent. The threadfin shad appears to have erratic occurrence in this section of the river, taken occasionally and in small numbers in the repeated sampling at McAlpine Lock. However, more than 1,900 individuals were taken in one collection at Lock 44 (mile 663.2) at Leavenworth, Ind., about 50 miles below Louisville. In weight, the gizzard shad contributed slightly more than 60 per cent of the total for all fishes in this area, followed by the skipjack herring (10.2 per cent), the freshwater drum (8.4 per cent), the channel catfish (4.1 per cent), and the emerald shiner (4.0 per cent).

Many of the fishes collected in Section 7 were taken between McAlpine Lock and Dam and the town of West Point at the mouth of the Salt River. Considerable sampling was conducted here with hoopnets, the electric shocker, and seines. In addition, some streams on the Indiana and Kentucky shores were sampled on several occasions, particularly Harrod's Creek, Beargrass Creek, and Goose Creek in Jefferson County, Ky.

Section 8 (miles 700-800): The gizzard shad was numerically the most abundant species taken and made up 55.7 per cent of the total catch. It was followed in order by the freshwater drum (24.5 per cent), the emerald shiner (6.2 per cent), the channel catfish (3.1 per cent), and the threadfin shad (2.9 per cent). These five species made up 92.4 per cent of the numbers taken. Here again, the two numerically most abundant fishes were also the most abundant by weight. The more than 7,000 lbs. of gizzard shad taken in this area during the study period constituted 80.6 per cent of the total weight of fishes taken; other principal species were the freshwater drum (8.1 per cent), the channel catfish (4.0 per cent), the blue catfish (1.6 per cent), and the carp (1.4 per cent), and all together they made up 95.7 per cent of the total weight; this is the second instance in which the percentage of total weight contributed by the first five species was greater than that contributed by the five most numerous species.

Section 9 (miles 800-900): The most numerically abundant fish was the freshwater drum, which comprised 25.0 per cent of the total number of fishes taken, followed in order by the gizzard shad (21.5 per cent), the blue catfish (14.1 per cent), the channel catfish (11.0 per cent), and the emerald shiner (5.7 per cent). These fishes made up 77.3 per cent of the total catch. In weight, the gizzard shad comprised 33.2 per cent of the total catch and the carp 18.4 per cent, followed in order by the freshwater drum (13.6 per cent), the channel catfish (10.7 per cent), and the flathead catfish (5.1 per cent), for a total of 81.0 per cent.

Section 10 (miles 900-981): In this section, the gizzard shad was numerically the most abundant fish and contributed 30.1 per cent of the total catch, followed by the freshwater drum (17.4 per cent), the threadfin shad (16.0 per cent), the emerald shiner (5.1 per cent), and the channel catfish (4.8 per cent), for a total of 73.4 per cent. The gizzard shad, as well as being the most numerous fish in the collections, also contributed the most weight. It made up 25.3 per cent of the total weight and was followed in order by freshwater drum (20.7 per cent), the carp (14.0 per cent), the flathead catfish (6.6 per cent), and the channel catfish (6.3 per cent), for a total of 72.9 per cent.

C. Families and Ecological Groupings

The distribution of fishes in the Ohio River follows a general pattern based on the ecological requirements of the different species or related groups. Some fishes, although quite unrelated phylogenetically, live in similar areas, use the same sorts of foods and are commonly taken in the same collections. Other fishes, although very closely related, are seldom found together, have different food habits, and occupy different niches. Accordingly, the following discussion of the various groups of fishes is arranged more or less by family groups, food and feeding habits, general habits, and where they live in the river. The groups considered are the small minnows; the shad, herring, and drum; the catfishes; the deep-bodied suckers and sucker-like fishes and the round-bodied suckers; and the game or sport fishes.

1. Small Minnows

The data presented so far indicate that the smaller minnows which belong to the genera Notropis, Hybopsis, Hybognathus, Pimephales, etc., but excluding the carp and the goldfish which reach a much larger size, made up by far the greatest numbers of fishes collected. In fact, the emerald shiner, the mimic shiner, the silver chub, the sand shiner, the bluntnose minnow (Pimephales notatus), the river shiner (Notropis blennius), and the silvery minnow (Hybognathus nuchalis) were among the 21 most numerically abundant species taken (Table 12) and made up more than two-thirds of all fishes taken in all collections. Of the 741,438 fishes taken during the study, 498,946 (67.3 per cent) were of these seven species. By far the most abundant of these was the emerald shiner with 428,463, comprising 57.8 per cent, followed in order by the mimic shiner with 50,241 specimens (6.8 per cent), the silver chub with 11,789 specimens (1.6 per cent), the sand shiner with 3,633 individuals (0.5 per cent), the bluntnose minnow with 2,023 individuals (0.3 per cent), the river shiner with 1,416 individuals (0.2 per cent), and the silvery minnow with 1,381 individuals (0.2 per cent). Even though they contributed more than two-thirds of the total numbers of fishes, these seven species contributed only 1,519 lbs. (4.7 per cent) to the total weight of all fishes taken, and of this amount, 3.7 per cent was contributed by the emerald shiner. Thus, the other six species of minnows together contributed less than 1.0 per cent of the total weight of all fishes taken.

The small minnows are much more abundant in the collections in the upper half of the river than in the lower half (Fig. 25), and are the most abundant fishes in each of the first five 100-mile sections of the river. Below that area they never ranked higher than third except in the area around Louisville. The apparent relative abundance near Louisville is probably traceable to the extensive sampling of the small chamber at McAlpine Lock on a year-round basis. This part of the study will be considered in detail later.

However, some minnows are more abundant in the lower river than in the upper river. Among these are the silverband shiner (Notropis illecebrosus) and the silvery minnow. These two species were not taken in abundance in any of the collections farther upstream than mile 800. In other words, they were common only in the lower 181 miles of the river. On the other hand, the sand shiner was taken only in the first 400 miles below Pittsburgh. Four species of minnows, the emerald shiner, the river shiner, the mimic shiner, and the silver chub, were commonly taken throughout the entire length of the river. However, the emerald shiner was more abundant in the upper river than at the lower end and relatively few specimens were taken in the lower 200 miles. The emerald shiner occurs in great schools of several thousand individuals in virtually all areas of the upper river, particularly around the lock chambers. Frequently, they can be seen in tremendously large schools as they swim along the guide walls, a phenomenon noticed near many of the lock chambers where population studies were made. In some instances, the fishes passed by in a steady stream for several minutes, and in such great numbers that, even though they moved relatively slowly, they could not possibly be counted.

The role played by the other minnows, such as the mimic shiner and the silver chub, is difficult to interpret without further study. These two species occur throughout the length of the river and apparently are no particular threat to the abundance of the emerald shiner, although they are present in relatively great numbers, as attested by the fact that more than 50,000 mimic shiners and more than 11,000 silver chubs were taken during the study. In the collections from the Allegheny River, the mimic shiners actually outnumbered the emerald shiners, and in the lower 200 miles of the Ohio River, the emerald shiner was outnumbered by both the silverband shiner and the silvery minnow. In no instance was the silver chub very abundant, although it was present in many of the collections. An excellent indication of the distribution of these fishes is the number of collections in which they were taken. Of the 129 collections from lock chambers and stream mouths taken by the University of Louisville during the three-year period, the emerald shiner occurred in 112 collections, the silver chub in 86, and the mimic shiner in 76. Thus each of these three species occurred in well over half, and in the case of the emerald shiner, in nearly 87 per cent, of all collections. The distribution of these fishes will be considered later in more detail when we refer to the lock chamber studies and the treatment of waters in the mouths of tributaries.

2. Shad, Herring, and Drum

Data from the three-year study period and general observations by the various biologists in the field leave little doubt that the gizzard shad is by far the most abundant fish by weight in the Ohio River. The data from all collections show that the gizzard shad made up 44.6 per cent of the more than 16 tons of fish taken during the study period; in other words, more than 7 tons of gizzard shad were taken. In addition to the weight contribution, the gizzard shad was the second most numerous fish taken in all the collections (107,165 individuals made up 14.5 per cent of the total number). However, it is not evenly distributed throughout the river. The gizzard shad was not taken in any of the collections above Pittsburgh or directly in the Pittsburgh area, but it appeared in the collections about 30 to 40 miles downstream and became relatively more and more abundant downstream to an apparent peak in the Evansville, Ind. and Owensboro, Ky. area, as shown in Figure 26. Below that area the species began to decline in our collections, although it still was very abundant. The gizzard shad may be unable to cope with the highly acid waters in the Pittsburgh area coming from the Monongahela River. However, it does well throughout the rest of the river and is exceedingly abundant between Cincinnati and Paducah. In the area between 700 and 800 miles below Pittsburgh, the gizzard shad contributed 55.7 per cent of all the individuals taken and 80.6 per cent of the total weight of all fishes taken during the study period.

Closely related to the gizzard shad is the threadfin shad, which prior to this survey had not been recorded in the Ohio River basin upstream from the mouth of the Tennessee River. It was not reported in any of the lists of fishes from Indiana, Ohio, or Kentucky above that region. During this study, the threadfin shad was collected near Louisville on several occasions and was taken in at least one collection from the section above Louisville. Downstream from Louisville, the threadfin shad became increasingly more abundant toward the lower reaches of the Ohio River and near Cairo was quite abundant; in some collections it made up as much as 15 to 20 per cent of the total sample (Fig. 26). During the entire survey, the threadfin shad was most abundant in the lowest section of the river, where it contributed 16 per cent of the total number of fishes taken and made up 3.1 per cent of the total weight of all fishes. The threadfin shad is a relatively small fish compared with the gizzard shad. It seldom exceeds seven inches in total length, is considered an ideal forage fish, and has been dispersed widely over the country for this purpose. There is a possibility that the threadfin shad near Louisville resulted from introductions in watersheds of tributaries upstream. However, since specimens were taken in an otter trawl in the impoundment above McAlpine Dam and from Lock No. 33 at Maysville, Ky., there is good evidence that the species is well established. Also, the collection of six hybrids between the threadfin shad and the gizzard shad from the Ohio River between Louisville and Cairo, Ill., indicates that both species spawn successfully in this area (Minckley and Krumholz, 1960). (Since publication of that paper other individuals have been reported to those authors.)

Another species fairly closely related to the gizzard shad and threadfin shad is the skipjack herring. This species was taken in each of the 100-mile sections below Pittsburgh but not in any of the collections above Pittsburgh (Fig. 26). Its average abundance was not great in any section, although in a few collections it was taken in large numbers. For instance, at McAlpine Lock during the spring of 1959, more than 600 specimens were taken in one study. Apparently this potamodromous fish was trapped in the lock on its way upstream. Most of the specimens at that time seemed close to spawning condition. Skipjack herring were frequently observed slashing minnows below leaking lock gates and over sand bars in the open river.

In no section of the river did the skipjack herring make up more than 2 per cent of the total number of individuals taken. However, it made up more than 10 per cent of the total weight of all fishes taken in all collections in the first 100 miles immediately below Pittsburgh and in Section 7 in the vicinity of Louisville. The relatively large percentage in the latter section is traceable to the tremendous numbers taken in the spring of 1959 during two lock studies.

Another species of fish common in the lower two-thirds of the river is the freshwater drum. This species was taken in very small numbers in the first and second 100-mile sections below Pittsburgh, but downstream from about mile 200 it became increasingly abundant. The frequency distribution of the freshwater drum both by numbers and by weight for each of the 100-mile sections of the Ohio River is shown in Figure 26. In Section 6, the freshwater drum was the most abundant fish in the collections and made up more than 40 per cent of the total number of fishes taken. However, most of the individuals taken were small, and the total weight of the 11,675 specimens was only 190 lbs., 12 per cent of the total weight of fish taken from that section of the river. The freshwater drum is one of the most important food fishes in the Ohio River, equal to the catfishes in total catch.

3. Catfishes

Among the catfishes the channel catfish is by far the most abundant throughout the length of the Ohio River. It was the fifth most abundant fish taken during the study (22,722 individuals) and ranked third in total weight (3,557 lbs.) for all collections. The channel catfish is one of the most sought-after food fishes in the Ohio River; it is abundant and is readily taken by hoopnets and by hook and line. The channel catfish was taken in each of the 100-mile sections referred to earlier and was most abundant in Sections 5 and 6 of the river (Fig. 27). From the region of Pittsburgh, the channel catfish becomes increasingly abundant down to about Cincinnati, where it reaches its peak in population over the length of the Ohio River. It was most abundant in the collections from Section 5, where it contributed 26.2 per cent of all the fishes taken (Figs. 19, 27); there, 4,088 channel catfish weighed 995 lbs., an instance where 26.2 per cent of the total number of fishes contributed 26.7 per cent of the total weight.

Below Louisville, the abundance of the channel catfish is augmented to a certain extent by that of the blue catfish, which becomes increasingly abundant downstream (Fig. 27). Apparently the increased abundance of the blue catfish does not occur at the expense of the channel catfish. It is difficult to say just why the blue catfish does not occur in great numbers above Louisville. Certainly it can negotiate the falls of the Ohio during high water, but it is probable that the proper ecological conditions do not prevail in that region. The blue catfish reaches tremendous sizes and is considered a highly desirable food fish in the lower reaches of the river.

In the region of the Ohio River just below Pittsburgh, the most abundant catfish both in number and in weight was the black bullhead. This species was taken by virtually all methods of sampling used in this area including the electric shocker, gill nets, hoopnets, and by rotenone in lock chambers, backwaters, and stream mouths. Below this region it rapidly diminished in abundance, and its occurrence was only spotty downstream (Fig. 27). The other two bullheads, the yellow bullhead (Ictalurus natalis) and the brown bullhead (I. nebulosus), are distributed over the entire river length but are never very abundant; an individual was taken here and there, but never more than a few in any single collection.

One other catfish of note in the Ohio River is the flathead catfish, which occurs throughout the length of the river, being taken in each of the 100-mile sections of the stream (Fig. 27). It was never very abundant in any of the collections but it was consistently present in most. It was taken in hoopnets, by shocking, in lock shambers, in backwaters, and in stream mouths. During the study, specimens weighing more than 30 lbs. were taken. In no 100-mile section did the flathead catfish ever comprise more than about 6.5 per cent of the total weight of all fishes taken. The flathead catfish reaches large sizes and is excellent as a food fish.

The smaller species of catfishes known as madtoms (Noturus spp.) were taken throughout the entire length of the river, principally in the mouths of tributary streams, and occasionally in the lock chambers and backwaters.

4. Suckers

Another group of fishes to be considered is the suckers. This group can be divided on a structural basis into the deep-bodied suckers and the round-bodied suckers. The deep-bodied suckers include the various carpsuckers belonging to the genus Carpiodes, of which four species were included in the collections, the river carpsucker (C. carpio), the quillback (C. cyprinus), the plains carpsucker (C. forbesi), and the highfin carpsucker (C. velifer). Also included in this group are the buffalo, belonging to the genus Ictiobus, of which three species were taken in the collections: the smallmouth buffalo, the bigmouth buffalo (I. cyprinellus), and the black buffalo (I. niger). Thus, in this group of deep-bodied suckers there are seven catostomids, and arbitrarily, on the basis of food habits and other characteristics, the carp and the goldfish.

The distribution of the deep-bodied suckers in our collections indicated that members of these species were taken in all sections of the river but were generally more abundant in the upper river than in the lower stretches (Fig. 28).

In no section did they make up as much as 4 per cent of the total number of fishes taken, but they were relatively most abundant from mile 900 to mile 981. In the five sections of the river (Sections 0, 2, 4, 9, 10) where the combined group of deep-bodied suckers made up more than 20 per cent of the total weight of all fishes taken, the highest percentage was in Section 2, where they made up 50.6 per cent, and the lowest percentage was in Section 10, where they made up only 20.5 per cent.

Among the deep-bodied suckers, the distribution of the carpsuckers in our collections indicates that these fishes are not present in the upper reaches of the river. Only a very few carpsuckers were taken above mile 200, but there was a gradual increase in numbers from mile 200 to about mile 700, and from there downstream the numbers taken remained about the same. Much the same statement is applicable to the buffalofishes, which showed a general increase below mile 200 and then leveled off from about mile 600 to the mouth of the river.

The species responsible for the relatively great weight of deep-bodied suckers was not a sucker but a minnow, the carp. Although only relatively few carp were taken in the collections, they usually were of fairly large size and contributed 10.9 per cent to the total weight of all fish taken. This species was particularly abundant in the upper half of the river (Fig. 28), where in some collections it made up a considerable portion of the catch. For instance, in the collections of May, 1958 from Locks No. 14, 15, and 16, respectively, 128 carp weighed 566 lbs., 28 carp weighed 102 lbs., and 61 carp weighed 228 lbs. Thus, a total of 217 carp taken in three collections within one 100-mile section of the Ohio River weighed 896 lbs., an average of 4.13 lbs. each. Carp of similar size and numbers were present in the collections throughout the upper river. For the total collections of deep-bodied suckers, the carp was followed in order, both in number and weight, by the river carpsucker, the smallmouth buffalo, and the quillback (Table 12).

Among the round-bodied suckers, 10 species are included in this report. These are the white sucker, the blue sucker (*Cycleptus elongatus*), the northern hog sucker (*Hypentelium nigricans*), the spotted sucker, and the following six species of redhorse: the northern redhorse (*Moxostoma macrolepidotum*), the silver redhorse (*M. anisurum*), the shorthead redhorse (*M. breviceps*), the river redhorse (*M. carinatum*), the black redhorse (*M. duquesnei*), and the golden redhorse. Also taken during this survey were two species of chubsuckers, the lake chubsucker (*Erimyzon sucetta*) and the creek chubsucker (*E. oblongus*). However, in this report these two species of small round-bodied suckers are not included in the discussion of the other, larger, round-bodied suckers.

Round-bodied suckers were taken in collections in each of the 100-mile sections of the river (Fig. 29), and like the deep-bodied suckers, they were more abundant in our collections from the upper reaches of the river than in the lower parts. In contrast to the deep-bodied suckers, however, the round-bodied suckers made up more than 20 per cent of the total weight of all fishes only in Section 0. In Section 6, just above Louisville, they made up 10.6 per cent of the total weight of all fishes taken, and in only that section did the combined round-bodied suckers make up more than 1 per cent of the total number of fishes taken.

Among the round-bodied suckers, the white sucker is more abundant in the upper reaches of the river than anywhere else; most of that species in our collections were taken near Pittsburgh, and they gradually decreased in abundance from there down to the region of Louisville. No white suckers were taken below the 100-mile section including Louisville. Much the same distributional pattern existed in our collections for the northern hog sucker. The spotted sucker, however, appeared most frequently in the collections from the middle stretch of the river; it gradually increased from the region below Pittsburgh to above Louisville and then gradually decreased from there downstream. The high relative abundance near Louisville is traceable to a single collection from Goose Creek, Jefferson County, Ky. The blue sucker was found only in the region from Louisville downstream to Cairo.

The round-bodied suckers belonging to the genus Moxostoma were distributed generally over the upper reaches of the river, although a few were taken as far downstream as Section 9. However, the most abundant species, the golden redhorse, was most numerous in the regions above and just below Pittsburgh, gradually decreasing in abundance downstream. Of all round-bodied suckers in the collections, the golden redhorse was the most abundant and was followed in order by the spotted sucker and the white sucker.

When the totals for the deep-bodied and the round-bodied suckers are combined, the percentage frequency in numbers for each of the 100-mile sections ranged from a low of 0.1 per cent in Section 2 to 3.6 per cent in Section 10; and in total weight from a low of 2.7 per cent in Section 8 to 65.5 per cent in the area above Pittsburgh. In the Ohio River itself, the greatest weight was taken in Section 2, where 54.0 per cent of the total weight was contributed by all suckers. Although the suckers were not very abundant numerically in the collections, they did contribute slightly more than 15 per cent of the total weight of all fishes taken. This is slightly less than the 17 to 18 per cent contributed by all the catfishes taken in the collections.

5. Sport Fishes

Discussion of the fishes of the Ohio River would not be complete without some reference to the game or sport fishes. These include generally the three groups of sunfishes: the smaller ones belonging to the genus Lepomis; the larger ones, commonly known as the black basses, belonging to the genus Micropterus; and the intermediate-sized group, the crappies, of the genus Pomoxis.

Also considered among the sport fishes are the serranids, particularly the white bass (Roccus chrysops), and the pike perches, sometimes called jack salmon, of the genus Stizostedion.

The black basses, of which there are three in the Ohio River, the largemouth bass (Micropterus salmoides), the smallmouth bass (M. dolomieui), and the spotted bass (M. punctulatus), are perhaps among the most highly prized sport fishes. The distribution pattern of the black basses, as shown by our collections, indicates that the smallmouth bass occurred only in the upper reaches of the river, above about mile 300, with a few specimens taken farther downstream. The most abundant of the three is the spotted bass, sometimes called the Kentucky bass, which was taken very nearly over the entire length of the river. It never was greatly abundant in any collection, but fine specimens weighing up to 2 lbs. were taken in various sections of the river. Similarly, the largemouth bass was scattered in abundance over the entire river. Actually, a greater weight of largemouth bass was taken than either of the other two, but it was not so numerous as the spotted bass.

Of the crappies, the white crappie (Pomoxis annularis) was more abundant in our collections than the black crappie (P. nigromaculatus). Neither species was abundant, but both were taken more frequently in the lower two-thirds of the river than in the upper third, and the latter seemed more common in the lower part of the river. Generally speaking, the black crappies taken were larger than the white crappies.

Among the smaller sunfishes, several are of little use to the sport fisherman, such as the orangespotted sunfish (Lepomis humilis) and the flier (Centrarchus macropterus), which are characteristic of the lower river. Of the other species of sunfishes, sometimes called panfishes, the most abundant were the bluegill (L. macrochirus) and the longear sunfish (L. megalotis), and these were followed rather closely by the green sunfish (L. cyanellus). None of these fishes, however, contributed greatly to the total weight of fishes taken in any particular section of the river, although more than 1,000 each of bluegills and longear sunfish were taken during the entire study (Table 12). Two other species, the redear sunfish (L. microlophus) and the pumpkinseed (L. gibbosus), were taken in various collections over the three-year period. However, it should be noted here that the pumpkinseed is an upriver fish and does not occur, so far as we know, in Kentucky waters. The only specimens taken were collected in Pennsylvania and West Virginia.

Another group of sport fishes is the perches, of which three species taken during the study are considered good sport fishes. These are the two pike perches, the walleye (Stizostedion vitreum vitreum) and sauger (S. canadense), and the yellow perch (Perca flavescens). The latter was taken primarily in the upper reaches of the Ohio River in the area around Pittsburgh and in upper West Virginia waters, although a few specimens were taken in Kentucky waters. The walleye is quite common above Pittsburgh and gradually decreases in abundance down to the region of Louisville. The sauger, on the other hand, apparently is most abundant in the lower reaches of the river and is fairly common upstream as far as Huntington, W. Va. Thus there appears to be an area of overlap between Louisville and Huntington where both species are found. In some of the collections from lock chambers several nice specimens of either walleye or sauger were taken, some weighing well over 2 lbs.

A group of small fishes in the perch family, the darters, was represented by several species that usually occur in areas where the water flow is rather swift. However, several specimens were taken from lock chambers. The list of darters taken is given in Appendix II of this report.

6. Other Groups

Among the other kinds of fishes taken in the river which are worthy of notice are the lampreys. Several specimens of the Ohio lamprey (Ichthyomyzon bdellium) were taken, mostly from lock chambers. Although several species are known to inhabit the Ohio River, no others were taken during the study.

A unique fish in the Ohio River is the paddlefish (Polyodon spathula), which reaches sizes of more than 100 lbs. The largest specimen taken during the study weighed about 30 lbs. and was 48 inches long. The paddlefish is taken frequently by commercial fishermen in the lower river upstream as far as Louisville, especially during the spring. However, individual specimens were taken in collections near Huntington and Parkersburg, W. Va., and from the Kanawha River.

Four species of gar belonging to the genus Lepisosteus occur in the Ohio River. The commonest of these in our collections was the longnose gar (L. osseus), and it was followed in abundance by the shortnose gar (L. platostomus). Although the spotted gar (L. oculatus) was reported in samples from the lower river, specimens were not preserved for verification, and it is not included in the list of species taken in this study. The alligator gar (L. spathula) is known to occur in the lower reaches of the river but was not taken in our collections.

Several American eels were taken during the study period, the largest of which was about 3 feet long. One of the common native fishes in the lower reaches of the river is the bowfin, which inhabits swampy areas and bayous. Of the 22 individuals collected, 21 were taken in the two sections of the river downstream from Evansville, Ind., and the other specimen was taken from Lock No. 37 near Sayler Park, Ohio.

In addition to the many fishes listed in Appendix II, several other species known to occur in the Ohio River were not taken in any of our collections. Among these are the rock sturgeon (*Acipenser fulvescens*), the burbot (*Lota lota lacustris*), and the above-mentioned gars. On several occasions members of the study group have seen rock sturgeon taken by fishermen from the Ohio River at Louisville; and alligator gar have been seen on several occasions by members of the group, especially in the lower parts of the river, below Paducah. In the spring of 1960, several specimens of burbot were taken by a commercial fisherman in nets near Cincinnati, Ohio, and two of these specimens are preserved in the collections at the Department of Biology, University of Louisville. This constitutes a new record for this species in this part of the Ohio River (Clay, 1962).

There are also several species of small minnows which probably occur in the lower parts of the Ohio River near its confluence with the Mississippi River. This statement is based on the known occurrence of these species in the Mississippi River in that general region.

D. Frequency of Occurrence in Collections

From another point of view, the distribution and relative abundance of fishes from the Ohio River may be indicated by the number of collections in which they were taken (see Appendix II). From these data, it is apparent that the channel catfish occurred in more collections than any other individual species, being taken in 228 (66.9 per cent) of the 341 collections. It was followed in order by the gizzard shad, in 220 collections, the emerald shiner in 215, the freshwater drum in 193, the carp in 184, the silver chub in 176, and the flathead catfish in 169. These seven species are the only ones that occurred in at least half the collections. In addition, six other species of fishes occurred in more than 100 collections but in fewer than half the collections. These are the skipjack herring in 147 collections, the bluegill in 146, the river carpsucker in 126, the white crappie in 120, the longear sunfish in 107, and the mimic shiner in 100 collections. Thus there were 13 species of fishes that occurred in 100 or more of the 341 collections taken.

In addition to those 13 species, there are another 13 that occurred in 50 or more collections but in fewer than 100. These are the green sunfish in 92 collections, the black crappie in 86, the smallmouth buffalo in 83, the black bullhead in 77, the spotted bass in 75, the bluntnose minnow in 73, the river shiner in 73, the longnose gar in 67, the blue catfish in 67, the largemouth bass in 62, the goldeye (*Hiodon alosoides*) in 57, the spotted sucker in 55, and the warmouth (*Chaenobryttus gulosus*) in 50 collections. Thus, of the 131 species of fishes taken in the 341 collections, only 26, slightly less than 20 per cent of all the fishes taken, occurred in 50, which is only 14.7 per cent of all the collections; and only 7, that is, only about 5 per cent, occurred in more than half, and another 5 per cent occurred in 100 collections but fewer than half, and another 10 per cent in more than 50 but fewer than 100.

Conversely, there were 22 species of fishes each of which was taken only once in the 341 collections. This group makes up about 17 per cent of all fishes taken. In addition, another 9 species were taken in only two collections each. Thus there is a total of 31 species--almost one-fourth of the total species list--each of which was taken in no more than two of the 341 collections; whereas there were 26 species each of which was taken in 50 or more collections. In addition to the 31 species taken in either two or one collection each, there are 11 additional species that were taken in only three collections. Thus, very nearly one-third of all the species taken during the entire study were taken in three or fewer collections.

Here it must be pointed out that the number of collections in which a species of fish was taken during this study is not necessarily an indication of its relative abundance, but rather gives valuable information on the ease of capture by a variety of methods. For instance, there is little doubt that the emerald shiner is the most numerous species in the Ohio River, and it was taken in 192 (85.3 per cent) of the 225 rotenone collections, while the channel catfish was taken in 181 (80.4 per cent) of those same collections. At the same time, the channel catfish was taken in about half the hoopnet catches, but no emerald shiners were taken because they were too small to be retained by the nets. Conversely, the fact that any species of fish was taken in only three (0.9 per cent) or fewer of the 341 collections is a good indication that such species are not very abundant.

E. Rotenone Collections

1. Lock Chambers

More collections were taken by using rotenone in lock chambers than in any other sampling category, and more fish, both in number and in weight, were collected by this method. Before discussing the studies on the various lock chambers, it seems advisable to list the locks and dams, together with their sizes and locations. In the main stream of the Ohio River between Pittsburgh, Pa., and Cairo, Ill., there were 41 locks and dams at the beginning of the study period (Table 15). The first three of these locks and dams, Emsworth, Dashields, and Montgomery, are high permanent concrete dams located at miles 6.2, 13.3, and 31.7, respectively, below Pittsburgh. These three structures replaced what would have been the first seven numbered dams in the river.

Lock No. 8, the first to bear a number, is located at Chester, Pa., at mile 46.4, and is the last Ohio River lock within Pennsylvania. Locks 9 through 29 are located in West Virginia waters; however, there is a high dam at Gallipolis, Ohio, which is the only roller dam on the Ohio River. This dam replaced Locks 23, 24, 25, and 26. Thus, all locks numbered 30 or higher are in Kentucky waters. However, there is no Lock No. 40 or Lock No. 42, and the lock numbered 41 has been renamed McAlpine Lock and is located at Louisville. While the study was in progress, several new high dams were being built by the Corps of Engineers of the U.S. Army at various locations along the Ohio River. New locks and dams have been completed at Greenup and Louisville, Ky.; three are under construction, and three are in the planning stage.

At present there are three different sizes of lock chambers in the Ohio River. The regular-sized lock chambers, of which there were 39 at the beginning of the study, are 110 by 600 feet and have an average area of 1.52 acres. (Roller-gate chambers are 1.52 acres and mitre-gate chambers are 1.64 acres, but the difference in area is so negligible that it will be disregarded here. The 1.52-acre figure is used in the computations in this report.) The small lock chambers, of which there are five, are 56 by 360 feet and have an area of about 0.46 acre each. The new large locks are 110 feet by 1,200 feet and have an area of about 3.03 acres. During the three-year period, each lock chamber in the main stream of the Ohio River was treated with rotenone at least once. In addition, 12 studies were made in small-sized chambers in principal tributaries to the Ohio River; six lock chambers were sampled once, and two were sampled three times.

All together, 35 of the 124 studies in lock chambers in the main stream of the Ohio River were made in the small chambers. The remaining studies, with the exception of two made in the new large chambers at Markland Dam and Greenup Dam during 1959 by the crew from the Kentucky Department of Fish and Wildlife Resources, were made in the regular-sized chambers.

The studies made in small chambers comprised 1 at Emsworth Dam, 1 at Dashields, 4 at Montgomery, 1 at Gallipolis, and 28 in the auxiliary chamber of McAlpine Lock at Louisville. The numbers of fishes taken in those studies ranged from a low of 213 in the first study at Montgomery Lock to a high of 18,761 at McAlpine Lock on Oct. 9, 1959. The weights of fishes taken ranged from 9 lbs. for the third study at Montgomery Lock to about 570 lbs. at Louisville on May 4, 1959.

Based on geographic location below Pittsburgh, in the six studies made at Emsworth, Dashields, and Montgomery Locks, a total of 182.2 lbs. of fish were taken, for an average of 30.3 lbs. per study. During the single study at Gallipolis, 4,074 fishes were taken which weighed 170 lbs. In the 28 studies at Louisville, 11 were made in 1957, 9 in 1958, and 8 in 1959, during which respective totals of 21,535 fish that weighed 712.6 lbs., 23,994 fish that weighed 1,631.1 lbs., and 29,364 fish that weighed 1,538.2 lbs.

were taken, for a total of 74,893 fishes which weighed 3,881.9 lbs. for an average of 138.6 lbs. per study. Actually, at Louisville the weight of fishes per study ranged from 10.4 lbs. on Jan. 30, 1958, to 569.8 lbs. on May 4, 1959. On a basis of surface area of a lock chamber, the average weight recovered per study was 301.3 lbs. per acre.

The number and weight of each of the 16 most abundant species of fish taken from the small chamber at McAlpine Lock during each of the three years of the study, together with the total for the entire three-year period, are listed in Table 16. During those 28 studies, 46 species of fishes were taken; 36 in 1957, 32 in 1958, and 28 in 1959. This intensive study of the auxiliary chamber at McAlpine Lock corroborates the findings for larger chambers at different localities in the river that the most abundant fish numerically is the emerald shiner, followed in order of numerical abundance by the gizzard shad and the freshwater drum.

Of the remaining 36 species taken but not shown in Table 16, the black bullhead was the most abundant with 42 individuals and was followed in order by the river carpsucker, 34; the bluntnose minnow, 31; the longear sunfish, 19; the threadfin shad, 17; the stripetail darter (Etheostoma kennicotti), 13; the brown bullhead, 10; the longnose gar, 9; the white crappie, 8; the mooneye (Hiodon tergisus) and the silvery minnow, 7 each; the common shiner (Notropis cornutus), 6; the sauger and the quillback, 5 each; the spotted bass and the black crappie, 4 each; the white bass, the spotted sucker, and the rock bass (Ambloplites rupestris), 2 each; and the following ten species each with only a single specimen: the paddlefish, the shortnose gar, the largemouth bass, the American eel, the smallmouth bass, the white sucker, the yellow bullhead, the stoneroller (Campostoma anomalum), the spotfin shiner (Notropis spilopterus), and the tadpole madtom (Noturus gyrinus).

Of the 16 species listed in Table 16, only the emerald shiner and the freshwater drum were taken in all 28 collections. Three other species, the gizzard shad, the silver chub, and the channel catfish, were taken in 27 collections, and two species, the carp and the flathead catfish, were each taken in 23. The only other species taken in more than half the 28 collections was the skipjack herring, which was present in 18. Thus, only 8 (about 17 per cent) of the 46 species were taken in more than half the collections. Conversely, there were 15 species (about 33 per cent) each of which was represented in only one collection and an additional 4 species each of which was taken in only two collections.

These findings are generally similar to those for the regular-sized mainstream lock chambers, which will be discussed later. That is, relatively few species made up the bulk of the number and weight of fishes taken, whereas the greater numbers of species are represented in the catches by relatively few individuals. The data in Table 16 also indicate that the same three species of fishes that were most abundant numerically in the over-all study occurred in the same order of abundance in the studies at

McAlpine Lock. However, the three species that contributed most of the weight in the series of studies at McAlpine Lock, the gizzard shad, the skipjack herring, and the freshwater drum, were not the same as those in the over-all study. This discrepancy is difficult to explain.

Of the remaining 89 studies of lock chambers in the main stream of the Ohio River, 87 were made in the regular-sized chambers and 2 in the new large chambers. Of the 87 studies in the regular-sized chambers, 18 were made in 1957, and the 58,864 fish collected during those studies weighed 5,862.0 lbs. Forty-three were made in 1958 during which 257,419 fish having a total weight of 10,868.4 lbs. were collected; and 26 were made in 1959, when a total of 101,465 fish collected weighed 2,689.3 lbs. The total number of fish collected from regular-sized lock chambers during the three-year period was 417,748 individuals that weighed 19,419.7 lbs.

In the regular-sized lock chambers, the weights of fish collected ranged from 0 to 3,566.9 lbs., and the average for the 87 collections was 225.8 lbs. per collection. As mentioned previously, the surface area of the regular-sized lock chamber is 1.52 acres, so it follows that the average weight recovered per study was 148.6 lbs. of fish per acre.

In the new large lock chambers, the study at Markland Lock, near Markland, Ind., on May 13, 1959, yielded 2,338 fish that weighed 277.8 lbs.; whereas the study at Greenup Lock on June 10, 1959, yielded 692 fish that weighed 116.2 lbs. Thus the total for those two studies was 3,030 fish that weighed a total of 394.0 lbs., and the average for the two is 197 lbs. Here again, if this yield is considered on the basis of lock chamber surface area of 3.03 acres, the average yield from the two new large lock chambers was 65.0 lbs. per acre.

In all the findings from these lock chambers, it is readily apparent that a very few species made up the bulk of the number and weight of fishes taken, and that a relatively great number of species is represented in the catches by only a few individuals.

In combining all studies from the mainstream lock chambers--that is, those of the small-sized chambers, the regular-sized chambers, and the large chambers--there were 29 such studies in 1957, which yielded 80,399 fish that weighed 6,574.6 lbs. In 1958, 55 such studies yielded 281,413 fish that weighed 12,499.5 lbs., and in 1959, 40 studies of lock chambers in the main stream of the Ohio River yielded 133,859 fish that weighed 4,622.7 lbs. (Table 17), and the total catch for the three years for all mainstream lock chambers was 495,671 fish that weighed 23,696.8 lbs.

There are small lock chambers located in the principal tributaries to the Ohio River, and on occasion during the three-year study period, some of these lock chambers were sampled. Six such collections were made in 1957 and included studies on three lock chambers in the Allegheny River and one in the Monongahela River in Pennsylvania, and one each in the Green River and the Cumberland River in Kentucky. During 1958, two such studies were made in Kentucky, and one was made in the Kanawha River in West Virginia. In 1959, three studies were made on the Kentucky River in Kentucky. The total number and weight of fishes taken from the lock chambers in streams tributary to the Ohio River are listed in Table 17. From these data it is apparent that the six studies in 1957 yielded an average of 77.5 lbs. of fish per study. The three studies in 1958 yielded an average of 168.7 lbs. per study, and the three taken in 1959 yielded an average of 94.2 lbs. per study. For the three-year period, the total number of fishes taken from the lock chambers in the tributary streams was 34,457 individuals that weighed 1,328.2 lbs., and the average for the 12 studies over the three-year period was 110.7 lbs. of fish per study. Since the average size of the small lock chambers in the tributary streams is about 0.46 acre, the average yield per acre was 240.7 lbs. per study. An analysis of the studies in lock chambers in tributary streams shows that there were three in the Allegheny River, one in the Monongahela River in Pennsylvania, one in the Kanawha River in West Virginia, and seven in Kentucky; three of these studies were in Lock 1 of the Kentucky River, three in the first lock upstream on the Green River, and one on the first lock upstream on the Cumberland River. The weight of fish taken from the four studies in Pennsylvania ranged from 0.1 to 105.9 lbs. per study, with an average of 36.4 lbs. The study in the Kanawha River in West Virginia yielded 30.8 lbs., and the seven studies in Kentucky ranged from 66.4 to 494.0 lbs., the latter taken from the first lock on the Green River on July 16, 1958.

The study on the Monongahela River which yielded only 0.1 lb. was made at Lock No. 3 at Elizabeth. For this study it is worthwhile to mention that the river was almost a pale chartreuse in color, and only two small bluegills were taken in the entire study. At the same time the pH of the river in the main stream registered 3.8. If we consider just the three lock studies in the Allegheny River, Locks 7, 8, and 9, they ranged from 19 to 105.9 lbs. with an average of 48.5 lbs. The average for the three studies from the Kentucky River was 87.8 lbs.; the average for the three studies from the Green River was 217.5 lbs.; and the single study from the Cumberland River yielded 229.0 lbs.

The data in Table 18 show that fishes from the mainstream lock chambers contributed at least two-thirds, by number as well as by weight, of all the collections in the river. In addition, when the locks in tributary streams are included, all lock chambers contributed 71.5 per cent of the number of fishes taken, and 76.6 per cent of the total weight of all fishes taken.

Several general conclusions may be drawn from the data on the studies in the mainstream lock chambers. The numbers and weights of fishes taken in the different 100-mile sections (Table 19) show there were generally smaller fishes in the collections from the upper river than from those downstream. The freshwater drum and the gizzard shad, although relatively very abundant in the lower river, were not taken in great numbers in the first 200 miles below Pittsburgh (Fig. 26). The carp was generally more abundant in the collections from the upper half of the river than in the lower half, whereas the deep-bodied suckers were relatively more abundant in the lower half (Fig. 28). The distribution of the round-bodied suckers differed according to the different species, some being relatively more abundant in the upper river and others in the lower river (Fig. 29).

Although studies in lock chambers were made in each of the 100-mile sections of the river, the same number of studies was not made in each section; 11 were made in Section 1, 9 in Section 2, 6 in Section 3, 15 in Section 4, 13 in Section 5, 7 in Section 6, 34 in Section 7, 11 in Section 8, 9 in Section 9, and 9 in Section 10. The data for these combined collections for each section are listed in Table 19. Actually, these data are informative only if there is some sound basis for comparison. Here again, the standard unit of pounds of fish per surface acre is the most useful.

The comparison is somewhat difficult because some collections in Sections 1, 3, and 7 were made in the small lock chambers, whereas two collections were made in the new large lock chambers, one each in Section 4 and Section 6; and the remainder were taken from the regular-sized chambers. Still, it is obvious from the data listed in Table 20 that there were very large differences from one section to another. For instance, Section 1 yielded a standing crop of 37.9 lbs. of fish per acre, based on the weighted average of the 11 lock-chamber studies, six of which were made in small lock chambers, and five of which were made in the regular-sized chambers. Section 2 has only regular-sized chambers and the standing crop recovered averaged about 124.4 lbs. per acre. The standing crops in Sections 3 through 6 ranged from about 70 to about 95 lbs. per acre. Section 7, however, showed a very sharp increase to about 230 lbs. per acre, and a still further increase to about 480 lbs. per acre appeared in Section 8. The reasons for the increase between Sections 6 and 7 are not readily apparent, but it is believed that the unexpected increase between Sections 7 and 8 is attributable directly to the tremendously large catches of gizzard shad from the lock chambers near Owensboro, Ky., and Newburgh, Ind., when considerably more than a ton of gizzard shad was taken from each of the two lock chambers. For the last two sections of the river, the standing crops remained at about the same level, 125 lbs. per acre.

Thus, if there is a general trend in the data, it indicates a rather erratic increase in average standing crop from Pittsburgh, Pa., downstream to the mouth of the river at Cairo, Ill.

In considering the total weight of 23,696.8 lbs. of fish taken in the 124 lock chamber studies in the main stream of the Ohio River (Table 19), there is an over-all average of 191 lbs. per study. However, as pointed out earlier, studies were made in three different sizes of lock chambers, 35 in small chambers, 87 in regular-sized chambers, and 2 in large chambers. The exact area of each chamber being known, the total surface area of the 124 chambers is about 153 acres. Thus the total recovered standing crop from all studies in the 124 lock chambers in the main stream of the Ohio River was about 155 lbs. per acre.

If the studies for each of the different sizes of lock chambers are considered separately, the data indicate that the 35 studies in the small chambers yielded 3,881.9 lbs. of fish; the 87 studies in the regular-sized chambers yielded 19,419.7 lbs. of fish; and the two studies in the new large lock chambers yielded 394.2 lbs. of fish. Thus the average recovered weights of fish for the three groups were 240.7, 148.6, and 65.4 lbs. per acre, respectively.

Based on our field experience, it is believed that, as an average, about half of all fishes killed in the lock chamber were picked up; in some studies more than half the dead fishes were recovered before they sank, and in others, fewer than half were retrieved. The ability of the crew to retrieve the dead fishes depended upon several circumstances, some of which were quite beyond their control. First among these is the size of the lock chamber. It is only logical to believe that a crew can pick up more of the dead fish in a small area than in a large area in a given period of time. Thus, the efficiency of pickup was believed to be greater in the small chambers than in the regular-sized chambers, and in the regular-sized chambers it was greater than in the new large chambers. From another point of view, however, it is possible that the size of the lock chamber may not be of primary importance; the guide walls below the lock chambers may act as weirs to lead whatever fish are below the chamber into the lock regardless of its size. Second, the weather is a very important factor. If there was a strong wind and the water was very rough, the fishes could not be seen and recovered as readily as when the water was calm. Also, it was considerably more difficult to retrieve the fishes during a rainstorm than during dry weather, and during very cold weather the dipnets froze as they were taken from the water and this impaired the ability of the crew to recover fishes. A third factor that played a very important role in some of the studies was the amount of time during which the lock chamber could be idled from river traffic. Every effort was made to allow at least three hours for any one study, but usually more time was available.

Thus, if because of the many factors to be taken into consideration in properly executing a study of the fish population in a lock chamber, and an average figure of 50 per cent recovery of all fishes is used, an estimate of about 300 lbs. of fish per acre for the Ohio River can be made, based on the studies in the lock chambers. Thus, by doubling the figure of 155 lbs. per acre mentioned previously, there would be an average in the neighborhood of 300 lbs. of fish per acre. Such a figure of course will vary with every part of the river under scrutiny.

In analyzing the data on the biomass of fishes in the various 100-mile sections in light of the above considerations, and by using the recovered weights as pounds per acre based on the size of the chambers from which the fish were taken, there is a sounder basis for comparison. Even then the comparison is somewhat difficult, because some of the collections in Sections 1, 3, and 7 were made in small lock chambers, whereas two were taken in the new large lock chambers, one each in Sections 4 and 6, and all the remaining studies were made in regular-sized lock chambers. The data for the recovered standing crops for each 100-mile section, as listed in Table 20, indicate clearly that there were very large differences from one section to another. For instance, in Section 1 there was a standing crop of 37.9 lbs. of fish per acre, based on the weighted average of 11 lock chamber studies, six of which were made in small lock chambers, and five of which were made in the regular-sized chambers. In Section 2, where there are only regular-sized chambers, the average standing crop for the nine studies was 124.4 lbs. per acre. The standing crops in Sections 3 through 6 range from about 70 to about 95 lbs. per acre.

a) Observations on the Effects of Industrial Pollution

It must be remembered that many lock chambers in the main stream of the Ohio River are located in areas where there is high industrial activity with consequent pollution of the river. Such pollution usually is followed by a depletion, perhaps, or at least a marked change in the species composition of the fish population. The effect of extensive pollution is known; virtually all aquatic life is destroyed. However, the effects of long-term, rather low-level pollution are not clearly understood. In this regard several observations were made during the study period by members of the crew in various locations.

One of the areas where collections had been made since August, 1957, was about 30 miles below Pittsburgh, in the vicinity of Montgomery Lock and Dam. All together, three studies of the auxiliary chamber had been made before the steel strike commenced in the summer of 1959. During the first study, on Aug. 29, 1957, nine species of fish were taken, and the 219 individuals collected comprised 100 black bullheads, 96 carp, 4 goldfish, 3 carp x goldfish hybrids, 10 bluegills, 2 green sunfish, 1 channel catfish, 1 yellow bullhead, 1 emerald shiner, and 1 river shiner. These fishes weighed a total of 20.4 lbs. In the second study at the same lock chamber, July 30, 1958, nine species of fishes were again taken, but these included the largemouth bass (2 specimens), the bluntnose minnow, the sand shiner, and the golden shiner, 1 specimen each, and did not include the bluegill, the yellow bullhead, the carp x goldfish hybrid, or the river shiner. All together, 213 fish were taken in this second study, and they weighed 25.1 lbs. Much the same picture prevailed during the third study on June 27, 1959, when 480 individual fish weighed only 9.0 lbs. Here again there were nine species of fishes, but 465 of the 480 specimens recovered were young-of-the-year black bullheads.

From these three studies it is apparent that relatively few fish were in the lock chamber at any one time and that the total weight of fish for the three studies was only 54.4 lbs., an average of 18.1 lbs. per study. Although 18 species of fishes were represented in the collections, 730 (80.0 per cent) of the 912 individuals were black bullheads and 109 (12.0 per cent) were carp, and these two species contributed 36.8 lbs. (67.6 per cent) and 11.7 lbs. (21.5 per cent), respectively, to the total weight of 54.4 lbs. for all fish from the three studies.

Within a few days after the beginning of the steel strike in 1959, the waters in the main stream of the Ohio River cleared up markedly, became more transparent, and improved in color and odor. On July 26, 1959, a fourth study of the auxiliary chamber at Montgomery Lock was made by the same crew using the same amount and kind of rotenone as in the study of June 27, 1959. During the July study, 2,587 fish that weighed 36.6 lbs. were recovered. Of these, 788, considerably fewer than one-third, were black bullheads. Among the other fishes collected were 20 species of which 10 had not been represented in any of the first three studies.

It is of particular interest to note that during the first three studies, 6 species of small minnows, the emerald shiner, the sand shiner, the river shiner, the golden shiner, the bluntnose minnow, and the silver chub, were represented by an over-all total of 31 individuals. On July 26, however, 12 species of minnows were taken in addition to the 6 species just mentioned; they were the ghost shiner (Notropis buchanani), the common shiner, the stoneroller, the bigeye chub (Hybopsis amblops), the creek chub (Semotilus atromaculatus), the mimic shiner, and the rosyface shiner. Furthermore, the 12 species were represented by a total of 1,583 individuals. Of these, the sand shiner with 750 individuals was most abundant, followed in order by the mimic shiner with 623 and the bluntnose minnow with 119. Of the other nine species of minnows, the bigeye chub and the rosyface shiner were represented by 24 individuals each, the emerald shiner by 20, the common shiner by 9, the silver chub by 6, and the stoneroller, the golden shiner, the ghost shiner, and the creek chub by 2 each.

The sand shiner and mimic shiner are considered clean-water fishes that cannot withstand much pollution other than silt in some instances. Thus, their occurrence in such relatively large numbers in the auxiliary chamber at Montgomery Lock during the cessation of steel production is indicative that they will re-invade previously polluted waters within a very short time after they have cleared up. Of even greater importance is the occurrence of the rosyface shiner and the bigeye chub, which are seldom, if ever, found in areas where there is even slight pollution.

Among the fishes other than minnows not collected during any of the first three studies but taken during the fourth were the white sucker, 97 individuals, and the western banded killifish (Fundulus diaphanus menona) and the yellow perch, 1 individual each.

Similar observations were made in the area below Huntington, W. Va., and Ashland, Ky. There, however, the differences in the species composition of the fish fauna were evident even while the steel industry was in full operation, because most pollution in the area was confined to the south side of the river and there was relatively little on the north side. These differences were noted principally in the catches by hoopnet and by electric shocking, probably because the currents in the river kept most of the pollutants in that area. Relatively few species were taken along the Kentucky shore. On the Ohio side, however, many more individuals and more species were represented in the catches. For instance, in the hoopnets, 10 species of fishes were taken: the channel catfish, the carp, the river carpsucker, the smallmouth buffalo, the white crappie, the black crappie, the longear sunfish, the bluegill, the sauger, and the flathead catfish. Of the species mentioned, only the first four were taken on the Kentucky side.

These findings were strongly substantiated by data from the electric shocker catches, in which 12 species were taken on the Ohio side of the river but only 6 from the Kentucky side. The 12 species were the longnose gar, the skipjack herring, the carp, the river carpsucker, the smallmouth buffalo, the channel catfish, the gizzard shad, the golden redhorse, the emerald shiner, the river shiner, the silver chub, and the flathead catfish. Of these, only the first six were collected from the Kentucky side. In addition, the individual specimens from the relatively clean waters along the Ohio shore were in much better condition (heavier-bodied) than any from the Kentucky side.

2. Mouths of Tributary Streams

Another principal source of data on the distribution of fishes in the Ohio River was obtained by sampling the mouths of tributary streams with rotenone. Here the methods differed somewhat from those used in the lock chambers. Usually the mouth of the stream or a part of the backwater in the stream was treated with emulsifiable rotenone. In some instances the crews went upstream to the first riffle before applying the rotenone; in others they merely treated the waters at the mouth of the stream. Insofar as possible all fishes killed were picked up, although in some instances, debris and/or vegetation hampered a complete pickup. Another method was to measure off an area estimated to be one acre with small-mesh seines and then to measure it to the nearest tenth of an acre and treat it with the proper quantity of rotenone to give the concentration of one part per million. After this measured area was blocked off with seines, the rotenone was applied, and all fishes were then picked up for at least two days. During the three-year period, 78 collections from stream mouths were made as follows: 16 in 1957, 29 in 1958, and 33 in 1959. The numbers and weights of the fish collected each year are listed in Table 17.

Of these 78 collections from tributaries to the Ohio River, 2 were made in Pennsylvania, both in Raccoon Creek, Beaver County; 16 in West Virginia, one each in Buffalo Creek (Brooke County), Wheeling Creek (Ohio County), Fish Creek (Marshall County), Little Sand Creek (Wood County), Little Sandy Creek (Jackson County), Sandy Creek (Jackson County), Mill Creek (Jackson County), Little Mill Creek (Jackson County), Old Town Creek (Mason County), Salt Creek (Mason County), Crab Creek (Mason County), Sixteen Mile Creek (Mason County), Eighteen Mile Creek (Mason County), Seven Mile Creek (Cabell County), Guyandot River (Cabell County), and Twelvepole Creek (Wayne County); 8 in Ohio, one each in Captina Creek (Belmont County), White Oak Creek (Lawrence County), Indian Creek (Claremont County), Boat Run (Claremont County), Little Indian Creek (Hamilton County), Rapid Run (Hamilton County), Muddy Creek (Hamilton County), and Great Miami River (Hamilton County); 8 in Indiana, one each in Tanner's Creek (Dearborn County), Laughery Creek (Dearborn and Ohio Counties), Indian Kentuck Creek (Jefferson County), Silver Creek (Scott and Clark Counties), Buck Creek (Harrison County), Indian Creek (Harrison County), Big Blue River (Harrison and Crawford Counties), and Little Blue River (Crawford County); 7 in Illinois, one each in Big Creek (Hardin County), Grand Pierre Creek (Pope County), Lusk Creek (Pope County), Big Bay Creek (Pope County), Seven Mile Creek (Massac County), Massac Creek (Massac County), and Cache River (Pulaski County); and 37 in Kentucky, Big Sandy River (Boyd County, Ky., and Wayne County, W. Va.) once, Little Sandy River (Greenup County) twice, Tygart's Creek (Greenup County) twice, Kinniconnick Creek (Lewis County) once, Cabin Creek (Mason County) once, Twelvemile Creek (Campbell County) once, Painter's Run (Campbell County) once, Elijah Creek (Boone County) once, Little Kentucky River (Carroll County) twice, Harrod's Creek (Jefferson County) three times, Goose Creek (Jefferson County) once, Bear Grass Creek (Jefferson County) four times, Salt River (Bullitt and Hardin Counties) twice, Doe Run (Meade County) three times, Sinking Creek (Breckenridge County) once, Blackford Creek (Hancock and Daviess Counties) once, Canoe Creek (Henderson County) three times, Highland Creek (Union County) twice, Drudge Ditch (Union County) once, Tradewater River (Union and Crittenden Counties) once, Deer Creek (Livingston County) once, Massac Creek (McCracken County) once, and Humphrey Creek (Ballard County) once. The mouths of three tributaries to the Allegheny and Monongahela Rivers were also sampled.

The total catch for the 81 collections included 147,345 fish that weighed 3,993.6 lbs. (Table 21), of which 6,605 fish that weighed 466.5 lbs. were taken in 1957, 129,833 that weighed 1,735.2 lbs. were taken in 1958, and 10,896 fish that weighed 1,794.4 lbs. were taken in 1959 (Table 17). These collections comprised 19.9 per cent of the total number and 12.2 per cent of the total weight of all fish taken during the three-year study period (Table 18).

An examination of the data on the weights of fishes taken from stream mouths in the various 100-mile sections of the river suggests a slight gradation from the upper end to the lower end (Table 19), although there are several irregularities in the gradation. However, when the data are analyzed on the basis of the average weight of fish per study for each section, as indicated in Table 21, there is no evidence of gradation. The greatest total weight of fish was taken in Section 4, which yielded an average 132.5 lbs. of fish per study, but the highest average weight was 140.0 lbs. per study in Section 1. The smallest total weight was in Section 7, near Louisville, where 14 collections yielded an average 12.5 lbs. per sample.

One of the outstanding differences between the collections in lock chambers and those in the mouths of tributary streams was the species composition of the catches. The fauna from the stream mouths varied considerably more than that from the lock chambers, although smaller numbers and weights of fishes were recovered. There were 108 species taken from the mouths of streams tributary to the Ohio River, compared to 83 species taken from lock chambers in the main stream. Species taken in lock chambers but not in stream mouths were the paddlefish, the mooneye, the blue sucker, the bigmouth buffalo, the black buffalo, the speckled chub (*Hybopsis aestivalis*), and the yellow bass (*Roccus mississippiensis*).

The 24 species taken from tributaries to the main stream of the Ohio River but not from main stream lock chambers were the creek chubsucker, the lake chubsucker, the northern hog sucker, the northern redhorse, the silver redhorse, the river redhorse, the shorthead redhorse, the Ozark minnow (*Dionda nubila*), the hornyhead chub (*Hybopsis biguttata*), the streamline chub (*H. dissimilis*), the river chub (*H. micropogon*), the pugnose minnow (*Opsopoeodus emiliae*), the mosquitofish (*Gambusia affinis*), the mud darter (*Etheostoma asprigene*), the rainbow darter (*E. caeruleum*), the slough darter (*E. gracile*), the johnny darter (*E. nigrum*), the cypress darter (*E. proeliare*), the orangethroat darter (*E. spectabile*), the spottail darter (*E. squamiceps*), the banded darter (*E. zonale*), the blackside darter (*Percina maculata*), the slenderhead darter (*P. phoxocephala*), and the river darter (*P. shumardi*).

In addition to the 78 studies made in the mouths of tributaries to the main stream of the Ohio River, studies were made in streams tributary to the Allegheny River, which in turn is tributary to the Ohio River. In one of those streams, a single brown trout (*Salmo trutta*) was taken. This was the only trout taken during the entire study.

3. Other Rotenone Studies

In addition to the studies in mainstream lock chambers and mouths of tributary streams, eight other collections were made with rotenone, seven in backwater areas behind the esplanades of lock and dam structures and in other parts of the main stream, and one in an open pool in the river during low water. The data summarizing these studies are listed as "Mainstream Backwaters" in Table 19. All together, these studies yielded a total of 24,693 fish weighing 2,319.3 lbs. for an average of 257.7 lbs. per study.

The single study in Section 7 near Louisville deserves special mention. Whenever the waters of the Ohio River recede during the summer months, an open pond about two acres in extent behind the old rock dike remains an isolated body of water. It is located at about mile 605, below the wickets at McAlpine Lock and Dam. On Aug. 6 and 7, 1957, this body of water was treated with rotenone similarly as in lock chambers, and 13,143 fish weighing 1,344.1 lbs. were recovered, sorted, and weighed. If the estimated area of two acres for the pond is realistic, the average standing crop was nearly 675 lbs. per acre, considerably more than the average standing crop estimated from the lock chamber studies. The most numerous species taken were the emerald shiner (7,039 individuals) and gizzard shad (5,398 individuals), which together made up 94.6 per cent of the total number taken. The gizzard shad, with 1,269.5 lbs., made up 94.4 per cent of the total weight. In addition to these two species, 23 others were taken in the study.

A summary of the rotenone studies during the three-year study period appears in Tables 17 through 21. Here it is shown that the 225 studies yielded 702,155 fish weighing 31,340.4 lbs. This total number made up 94.7 per cent of all fish taken during the entire study, and the weight made up 95.9 per cent of the total weight of all fish taken. Thus, it is obvious that the rotenone studies made during this study yielded the vast majority of the numbers, kinds, and weights of fish collected, and if these studies had not been made, very little could be said about the relative abundance and distribution of fishes throughout the Ohio River.

F. Other Methods of Collection

All together, 116 collections were taken by methods other than rotenone as follows (Tables 17 and 18): hoopnets, 39 collections; seines, 26; electric shocker, 20; otter trawl, 18; gill nets, 9; trammel nets, 2; and pole-and-line fishing, 2. Each of these methods employs gear that is particularly selective because of innate peculiarities in construction or use, and because of this selectivity, these methods were used to fill gaps in the information supplied by the rotenone samples. Some of the methods were used throughout the survey, whereas others, particularly the electric shocker, hoopnets, gill nets, and trammel nets, were not used extensively until the summer of 1959. During this last year of the survey, six locations on the Ohio River were studied rather intensively. The locations of these areas and the dates when the studies were made are listed in Table 22.

Hoopnetting was done during June, July, and August, 1959, at each location; two collections by hoopnets made during 1957 are also included in the data. The data are presented on the basis of total catch and are interpreted on the basis of trap nights, one trap night being one net fished one night. In practice, a trap night ranged from 12 to 24 hours.

Hoopnets were fished a total of 248 trap nights, the majority of the sets being made at five stations located downstream from major municipalities. The 710 fish taken weighed 705.8 lbs., an average of nearly 1 lb. per fish. A total of 28 species, plus hybrids between carp and goldfish, were taken in the nets. Of these, the channel catfish with 257 individuals, the black bullhead with 170, and the carp with 54 were the most numerous species. Five other species of which 25 or more individuals were taken included 37 freshwater drum, 34 white crappies, and 26 each of the flathead catfish, the spotted bass, and the black crappie. The weights of each of these eight species were: channel catfish, 217.2 lbs.; black bullhead, 57.4 lbs.; carp, 110.7 lbs.; freshwater drum, 16.6 lbs.; white crappie, 8.7 lbs.; flathead catfish, 57.7 lbs.; spotted bass, 14.7 lbs.; and black crappie, 7.7 lbs. Of these, the channel catfish, the carp, and the black bullhead made up 67.8 per cent of the total number and 54.6 per cent of the total weight, and the other five species contributed an additional 21.0 per cent of the number and 14.9 per cent of the weight for over-all totals of 88.8 and 69.5 per cent, respectively. Although only 12 blue catfish were caught in the hoopnets, they weighed 147.0 lbs. and contributed more than one-fifth (20.8 per cent) of the total weight.

Among the fishes taken by hoopnets that did not occur in the rotenone collections was a single specimen of the shovelnose sturgeon (*Scaphirhynchus platorynchus*).

The linear distribution of the catch by hoopnets in the various 100-mile sections of the Ohio River is shown in Table 19. The greatest number of fish taken per trap night was in the area below Cincinnati (June 13-19, 1959), where 92 per cent of the fish taken (82 per cent of the weight) were channel catfish. The abundance of this species may have been correlated with a spawning run since most of the individuals were ripe.

Collections with seines were made on 26 occasions, the majority in the vicinity of Louisville. The 26 collections yielded 32,024 fish that weighed 121.7 lbs. A total of 45 species of fishes were taken, two of which, the cypress minnow (*Hybognathus hayi*) and the banded sculpin (*Cottus carolinae*), were not present in the rotenone collections. Because of the lack of extensive seining collections other than those around Louisville, few conclusions may be drawn from the data (Table 19). On the other hand, the abundance of the emerald shiner and the gizzard shad confirms the results of the rotenone studies. These two species made up 92.9 per cent of the total number and 67.4 per cent of the total weight of all fish taken by seining.

Seining demonstrated, possibly better than any other method, the diversity of small fishes in the Ohio River. Although there were 32,024 fish that represented the 45 species taken, 30 species each made up less than 0.05 per cent of the total number. Of the 45 species in the collections, there were 7 suckers, 17 minnows, and 6 sunfishes. Of particular interest was the collection of two specimens of the banded sculpin from a sand bar at the head of Upper Blue River Island between miles 660 and 661, on Nov. 14, 1958. Upper Blue River Island is on the north side of the main channel of the Ohio River, and only a rather narrow, shallow channel separates it from the Indiana shore.

Electric shocking, as used in this study, selectively sampled the larger fishes in the populations, and, apparently, affected the catfishes to a lesser degree than the scaled fishes.

With the exception of the catfishes, the data from electric shocking approximate those from hoopnetting in the similarity of species and their relative abundance. There were 361 individuals that represented 30 species, and, of course, the carp x goldfish hybrid. Carp were taken in greater numbers (101 individuals) than any other species, and they also contributed more (185.2 lbs.) to the total weight. All together, only 31 catfish were taken including 26 channel catfish, 3 flathead catfish, and 2 black bullheads, and their total weight was only 11.4 lbs. So far as species composition is concerned, the greatest difference between the catches from the hoopnets and the electric shocker was the presence of six species of minnows in the latter collections. Such small fishes passed readily through the meshes of the hoopnets.

The data from electric shocking, when arranged by 100-mile sections of the river (Table 19), are too sparse to indicate any trend, but a perusal of the species composition of the various catches indicates that the number of species increased downstream.

The total catch of 361 individuals weighed 324.6 lbs., for an average of 0.9 lb. per fish. Certainly, if the 36 small minnows that weighed a total of 0.7 lb. were not included, the average weight would have been very nearly 1 lb.

Trawling was done primarily on an experimental basis, and 18 such collections were made during the study. In addition, many other collections were made in an effort to determine the best way to catch fish with this gear in the Ohio River.

Considerable difficulty was encountered from snagging the trawls on sunken debris and rocks. Trawling was most successful over submerged sandbars, and some midwater hauls were made with varying success. On the basis of the data obtained, it appears that further refinement of this technique should supply a sampling method for deep-water areas of the Ohio River that are otherwise relatively inaccessible. One of the values of trawling seems to be in collecting small bottom-feeding fishes from the deeper parts of the river in order to determine their food habits in that habitat.

The 18 hauls reported here yielded 5,660 fish referable to 29 species, and their total weight was 80.9 lbs. However, of this group, two species were predominant in the catch, the silver chub with 2,553 individuals that weighed 30.7 lbs., and the freshwater drum with 2,061 individuals that weighed 32.6 lbs. In addition, three other species were commonly taken, the channel catfish with 389 individuals that weighed 8.5 lbs., the emerald shiner with 273 individuals that weighed 1.5 lbs., and the gizzard shad with 193 individuals that weighed 2.5 lbs. These five species made up the bulk of the numbers (94.9 per cent) and weight (93.7 per cent) of the total catch by otter trawl.

Because the otter trawl was used principally in the vicinity of Louisville, with a few collections taken near Henderson, Ky., there are no data for comparison in the distribution of fishes over the length of the Ohio River (Table 19).

The collections made with miscellaneous gear (Tables 17, 18, and 19) included 9 with gill nets, 2 with trammel nets, and 2 with pole-and-line fishing. All together, 528 fish that weighed 105.3 lbs. were collected. Only 18 species were taken by these methods, and here again, the bulk of the catch consisted of only two species, the golden shiner with 235 individuals that weighed 14.6 lbs., and the gizzard shad with 174 individuals that weighed 31.2 lbs. Among the other relatively abundant species were the longnose gar and the shortnose gar with 24 and 14 individuals, respectively, and a total weight of 25.2 lbs., 22 white suckers that weighed 7.2 lbs., 17 black bullheads that weighed 3.6 lbs., and 13 channel catfish that weighed 9.7 lbs. These six species made up 94.5 per cent of the total numbers and 86.9 per cent of the total weight of all fish taken by these miscellaneous gear.

The large series of golden shiners, along with several pumpkinseeds, brown bullheads, and yellow perch, were taken in experimental gill nets in a "backwater" area above Montgomery Dam.

Because of the diversity of the collecting methods and the relatively small numbers of collections, no general conclusions may be drawn from the data. The data are included for completeness only, and are included in the figures for total fish taken during the study period.

The data from collections by methods other than rotenone indicate great differences in the composition of the fish fauna in catches by the various kinds of gear, as shown in Table 23. Here, the percentage frequency is indicated by the number of collections in which a species occurred and does not take into consideration the numbers of individuals present. There were 9 species taken in one-fifth of the hoopnet samples, 12 species in one-fifth of the samples by seining, 6 species in 20 per cent of the electric shocker collections, and 7 in 20 per cent of those taken by otter trawl. Of these, only the channel catfish were present in 20 per cent of the catches by each of the four types of gear.

It is obvious from the data listed that the species taken most frequently by hoopnets and the electric shocker usually are of larger size than those taken by the other two methods, which usually took greater numbers of small fishes. These differences are attributable directly to the limitations of the gear. The 116 collections by gear other than rotenone yielded 39,283 fish that weighed 1,338.4 lbs. Thus, 34.0 per cent of all the collections yielded only 5.3 per cent of the total numbers and 4.1 per cent of the total weight of all fishes taken throughout the study period (Table 19).

IV. CONCLUSIONS

In considering the data for all collections taken by all methods during the entire study period, a total of 741,438 fish that weighed 32,678.8 lbs. were picked up, sorted, and weighed. All together, 130 kinds of fishes, referable to 23 families, were taken in the collections. Of these, the emerald shiner was numerically the most abundant with 428,463 individuals comprising 57.8 per cent of the total catch, and the gizzard shad was the most abundant by weight and contributed 14,583.7 lbs. (44.3 per cent) to the total weight of all fish taken during the study period.

There is little doubt that the species composition and relative abundance of fishes in the Ohio River is considerably different from that first observed by Rafinesque and others. Since that time, man has installed a series of dams, along with various dikes and other improvements, as aids to navigation. In doing so, man has changed the river into a series of shallow lakes. As a result of these changes in the environment, many of the species that previously were abundant, such as the sturgeons, the paddlefish, the blue sucker, and the now-extinct harelip sucker (*Lagochila lacera*), and many of the smaller minnows and darters, are now quite rare and their distribution in the Ohio River is limited. Also, this series of "lakes", which approximates the conditions found in the lower portion of the Mississippi River or the conditions found in streams of the Plains Region, is gradually being invaded by many of the species more characteristic of lowland areas. Such species as the threadfin shad, the suckermouth minnow (*Phenacobius mirabilis*), and the orangespotted sunfish are among this group of invaders. Other species that probably have increased in abundance since the construction of the dams are the deep-bodied suckers, the gizzard shad, and, perhaps, some of the smaller sunfishes.

Of course, the ubiquitous carp is now a relatively abundant species in the Ohio River, along with its close relative the goldfish in some areas. Both these species show strong preference for quiet waters as furnished by the series of low dams.

With the completion of the high dams now under construction and under consideration, the fauna will change even more and will become more and more like that of other impounded areas and less and less like that of the Ohio River of the days of Rafinesque.

AQUATIC-LIFE RESOURCES

OF THE OHIO RIVER

SECTION IV

CREEL CENSUS DATA FOR

KENTUCKY WATERS OF THE OHIO RIVER

by James R. Charles

I. INTRODUCTION

A general sport fishing creel census on the Kentucky portion (lower 664 miles or mile 317 to mile 981) of the Ohio River was conducted during 1957, 1958, and 1959. The primary objective of this census was to procure data which would provide essential information on the present status of the sport fishery of the river. The chief items of information sought were: (1) an estimate of the total fishing pressure; (2) rate of fishing success (fish per hour); (3) estimated total harvest; (4) composition of the catch; (5) distribution of the catch along the river's course; (6) an estimate of the economic value of the sport fishery. This is the first extensive general creel census ever conducted on the Kentucky section of the Ohio River. No previous detailed studies are known that deal with utilization of the fish resources of this vast fishery potential.

Secondary objectives of the creel census included an interest in correlating the catch composition with known areas of pollution and with the species composition of the fish population as determined by rotenone sampling. Further, the resulting creel census information should allow comparison with creel data from other warm-water streams. Finally, the creel census section, as well as the other sections of this overall report, represents a pre-impoundment study of the Ohio River. High, fixed dams are to be built all along the river's course. The information derived from this study can serve as an index or standard against which any future creel census on the Ohio River may be compared. Undoubtedly, there will be shifts in the species composition as the river is changed from a partially-obstructed type of stream to a series of elongated lakes connected only by lock chambers. A future creel census would reflect many of the population changes and most certainly would show any changes in the type and degree of angler harvest and utilization. A knowledge of these values prior to the forthcoming change in the habitat was considered vital in understanding the dynamics of the changing population.

II. METHODS

A. 1957 Creel Census

All Kentucky Conservation Officers (C.O.'s) assigned to counties that border the Ohio River were personally contacted in a series of meetings held in early March of 1957. The scope of the entire project was explained to them and particular emphasis was placed on their role as census-takers during the life of the project. They were requested to interview as many sport fishermen as possible. These C.O.'s were relieved of any other creel census work and were instructed to concentrate their census efforts on the Ohio River. No predetermined creel census schedule was used in 1957; the C.O.'s were permitted to use their own discretion in collecting census data during the performance of their regular routine duties. The first interviews were made in March and interviewing continued each month through November. A total of 1,401 fishermen were interviewed during the first census year.

The creel census cards used in 1957 were designed to yield the following data: (1) number and sex of anglers; (2) resident or non-resident; (3) total cost of trip; (4) total trips per year to Ohio River; (5) boat or bank fisherman; (6) method of fishing employed; (7) type of bait used; (8) total time fished; (9) kind, number, and average length of species caught. Through an oversight, no space was provided on the 1957 card for recording whether the trip being reported was completed or not.

Because of a unique jurisdictional situation (Kentucky owns the Ohio River to the "low-water mark" on the opposite shores of Ohio, Indiana, and Illinois), those anglers fishing from the bank of the opposite shore were not interviewed by the C.O.'s at any time during the 3-year census period.

B. 1958 Creel Census

Several modifications were made in the second year's census. Each C.O. was assigned a definite number of creel cards to complete, the number depending upon the location of his county along the river. The upper section of the river was known to be polluted and was presumed to receive less fishing pressure because fish from this section reportedly taste "oily". Consequently, each of the C.O.'s assigned to that section of the river extending from the West Virginia line downstream to Mile 535 near Carrollton, Kentucky, was asked to interview 75 fishing parties during the census period, which ran from March through November. In the middle section, located from Mile 535 downstream to Mile 742 near Owensboro, Kentucky, the C.O.'s were requested to interview 100 fishing parties each. The river bordering the lowermost counties was thought to be relatively free from pollution, and the C.O.'s assigned to the lower section located from Mile 742 to the mouth of the river were requested to interview 125 fishing parties each. A total of 1,483 fishermen were interviewed during the second census year.

The census-takers were again reminded early in 1958 that all creel census questions pertained solely to the Ohio River. They were also instructed to note on each card whether or not it represented a completed trip.

The creel census card used in 1958 differed from that used in 1957 only in the absence of the boat-bank category. This item was deleted because it was learned that many of the census-takers were conducting the census from the bank, and that therefore, the ratio of bank to boat fishermen was not being measured.

C. 1959 Creel Census

Several major modifications were made in the 1959 creel census. A definite schedule was drafted requiring the interviewers to census the river on an alternating pattern of weekend days and week days. Noon was considered the midpoint of a creel census day. In recognition of the fact that fishermen usually tend to divide their daily fishing effort into two peak periods, the interviewers were required to census only before noon or after noon on any particular scheduled census day. The morning and afternoon periods were also alternated.

Complete instructions, with the key points emphasized, were printed on the back of the creel census schedule sent to each C.O. The creel card used in 1959 was again modified slightly in order to secure greater accuracy of census data. The single most important shortcoming of the Ohio River census-takers seemed to be the tendency to choose a disproportionate number of successful fishing parties for interviewing, as against the less successful or completely empty-handed. The enumerators were required to record the name and license number of each member of an interviewed fishing party on the back of the completed creel card. Because the majority had failed during the previous two years to note whether a card represented a completed or an incompleted trip, a space for recording this information was added to the 1959 creel card.

The 1959 census began April 25 (Saturday A.M.) and ended October 31 (Saturday P.M.). During this 190-day period, there were 55 scheduled creel census days. The census-takers were instructed that if a substitution became necessary because of illness or any other reason, the same day of the week that was missed, as well as the same time period (A.M. or P.M.), should be substituted. A minimum quota of five completed fishing party interviews per scheduled day was established, but no maximum limit on the number of fishing parties that could be interviewed was imposed. A total of 4,364 fishermen were interviewed during the 1959 census year.

Five total fisherman counts were made at monthly intervals along the entire Kentucky portion of the Ohio River. Because of the length of river involved, it would have been highly impractical to have requested a total fisherman count from the census-takers on each of the 55 scheduled creel census days. As a compromise, they were instructed to make five total counts, without interviews, during the census year. Project personnel divided the river into three approximately equal sections and made aerial total counts from three airplanes at the same time the census-takers were counting by motor boat. One aerial total count was cancelled because of bad weather conditions. The first total count was made on June 16 (Tuesday A.M.); the second was made on July 19 (Sunday A.M.) by boat only; the third was made on August 16 (Sunday A.M.); the fourth was made on September 17 (Thursday P.M.); and the fifth and final count was made on October 17 (Saturday P.M.).

After a poor beginning, characterized by flying too fast and at too great an altitude, the aerial observers became quite proficient at making total counts. Their accuracy approached, and possibly exceeded at times, that of the officers making the total counts by boat. It is believed that under average weather conditions, and with a modicum of experience on the part of the pilot and aerial enumerators, total fisherman counts can be made on large streams or open bodies of water with a high degree of accuracy. Binoculars helped overcome visibility problems and they also aided in determining whether the occupants of a boat underway were fishermen or pleasure boaters.

III. CREEL CENSUS RESULTS

There is no closed fishing season in Kentucky waters, nor was there, at the time of this study, a size limit on any species of fish. A daily creel and possession limit is imposed on certain species classed as game fishes. However, fishing activity is usually geared to the season of the year and tends to decline sharply with the advent of colder weather. Consequently, the creel census was conducted during the spring, summer, and fall months.

More than three times as many fishermen were counted in 1959 as in each of the two previous years. The 1959 data are presumed to be more accurate because they were collected on a predetermined schedule designed to randomize the effects of weather, days of the week, time of the day, etc. Therefore, while some comparisons will be made between years and between the different sections of the river, more reliance will be placed on the values and estimates derived from the 1959 creel census. All projected values will be based on creel data collected that year.

A. The Upper Section (218 miles)

The catfishes, carp, sunfishes, and freshwater drum dominated the catch from the upper section each year of the census (Figure 30). Collectively, these species made up at least 90.6 per cent of all fish caught annually. The catfishes far outranked all other species in the creel, accounting for 60.5 per cent, 53.2 per cent, and 59.5 per cent of all fish caught in this section during 1957, 1958, and 1959, respectively. Freshwater drum made up 6.0 per cent of the creel in 1957, 10.7 per cent in 1958, and 13.8 per cent in 1959. The catch of carp and the sunfishes also fluctuated from year to year. Carp made up 14.5 per cent of the total catch in 1957, 7.9 per cent in 1958, and 9.5 per cent in 1959. The sunfishes made up 13.2 per cent of the total catch in 1957, 19.5 per cent in 1958, and 7.8 per cent in 1959.

The crappies were the only remaining species that entered the catch in significant numbers and then only during 1958 when they accounted for 4.8 per cent of all fish taken in the upper section. They made up 1.8 per cent and 2.4 per cent, respectively, in 1957 and 1959.

Other species entering the creel in this section were white bass, black basses, rock bass, suckers, gars, and buffalo. No one of these species made up more than 2.4 per cent of the total catch.

The total recorded catch in the upper section of the river was 2,653 fish during the three-year census. Their combined total length was 31,610 inches, an average length of 11.9 inches per fish. These fish were caught by 1,698 anglers at an average rate of catch of 1.03 fish per hour in 1957, 1.09 in 1958, and 0.79 in 1959. The success rate in the upper section was greater each year than the rate in the middle section, but was less than the rate of catch in the lower section. A complete breakdown of the creel census results for each year and each section of the river appears in Table 24.

B. The Middle Section (207 miles)

The catfishes and freshwater drum ranked either first or second in the creel each year in the middle section of the river (Figure 31). Together they never made up less than 70.6 per cent of all fish caught. Other species which made up at least 5 per cent of the total catch in this section are the black basses, sunfishes, white bass, and carp.

The total recorded catch of 1,908 fishermen in the middle section of the river was 3,191 fish during the three-year census. Their combined total length was 35,189 inches, an average length of 11.0 inches per fish. The average rate of catch was 0.63 fish per hour in 1957, 0.06 in 1958, and 0.47 in 1959. The success rate in the middle section of the river was lower each year than in the other two sections. However, the game fishes always made up a greater percentage of the catch in this section (Table 24).

C. The Lower Section (239 miles)

Freshwater drum completely dominated the catch in the lower section of the river each year of the census (Figure 32). The catfishes ranked second each year in this section. Together, these species accounted for 79.8 per cent (1957), 75.4 per cent (1958), and 72.5 per cent (1959) of the total catch. White bass, the crappies and carp were the next most abundant species caught in the lower section. Each of these species made up at least 5 per cent of the total catch.

A total 13,315 fish were caught by the anglers censused in the lower river during the three-year period. These fish had an average length of 12.2 inches. They were caught by 3,869 anglers at an average rate of catch of 1.1 fish per hour in 1957, 1.4 in 1958, and 1.4 again in 1959. The success rate in the lower section was greater each year than in the other two sections of the river. During 1958 and 1959, the rate of catch in this section was more than double that of the middle section, and it was very nearly double in 1957 (Table 24).

IV. ANALYSIS

Of the 4,364 anglers interviewed in 1959, 83.6 per cent were interviewed before they had stopped fishing for the day, while 16.4 per cent had completed their fishing trip. The average size of the fishing parties was 1.6 anglers. The ratio of males to females was 87 to 13. Nearly 80 per cent of the anglers were Kentucky residents. (It should be remembered that the officers did not census anglers on the Ohio, Indiana, or Illinois shores, although they did interview boat fishermen.) Still fishing was by far the most important angling method used. Slightly more than 93 per cent of all anglers favored this method. Casting accounted for 4.0 per cent, trot lines were used by 1.7 per cent, trolling was practiced by 0.5 per cent, and miscellaneous methods were used by the remaining 0.6 per cent.

The rate of fishing success (fish per hour) was highest each year in the relatively unpolluted lower section of the river, but such a correlation between high catch rate and low pollution was less evident in the other two sections. The catch rate was next highest each year in the heavily polluted upper section, while it was lowest in the moderately polluted middle section of the river.

The total number of fishermen counted during the total count surveys in 1959 on the lower 664 miles of the Ohio River ranged from a low of 386 to a high of 1,161. Since the five total counts covered only half-day periods, the number of anglers theoretically must be doubled to measure the daily fishing pressure. The resultant average was 1,511 anglers per day, or 2.3 fishermen per mile. Projected, these data indicate that an estimated 287,090 anglers fished the Ohio River during the 190-day period covered by the 1959 creel census. The 4,364 anglers actually interviewed represent 1.5 per cent of the estimated annual fishing effort.

Based on an average of 2.6 fish per angler per fishing trip, it was estimated that 746,434 fish of all species were caught from the lower 664 miles of the Ohio River during the 190-day census period in 1959. These fish had an aggregate average length of 12 inches and an aggregate total weight of 522,504 pounds. If the market value of these fish, primarily catfishes and drum, is 25 cents per pound, then $130,626 worth of table food was taken from this section of the river by the sport fishermen during 1959.

The interviewed anglers estimated they would make 107,088 fishing trips, or 37 per cent of the total estimated fishing trips, on the Ohio River during 1959. This is an average of 25 trips per year for each angler. Again using their own estimates, the censused anglers actually spent $11,876 pursuing their hobby in 1959. Thus, the average angler spent $2.72 per trip or about $66 per year. Employing these data, the projected annual expenditures of fishermen censused in 1959 would approximate $290,000. It is believed that this figure is probably somewhat high, because an average of 25 fishing trips per year means the angler would have to fish at least once every other week of the year.

The total count data indicated that 287,090 anglers fished in the river during the creel census period. Utilizing the estimated cost per trip derived from the anglers actually interviewed, it was calculated that the total fisherman expenditure during the 190-day census period was $780,885. Even allowing a wide margin for error in techniques or estimates, it is still quite apparent that the Ohio River along Kentucky is now an extremely valuable natural resource, even though it receives very light fishing pressure in relation to its size and location.

AQUATIC-LIFE RESOURCES

OF THE OHIO RIVER

SECTION V

COMMERCIAL FISHING ACTIVITIES

IN THE KENTUCKY WATERS OF THE OHIO RIVER

by James R. Charles

I. INTRODUCTION

A separate investigation of the species composition of the commercial fishing catch from the Kentucky portion of the Ohio River was made during the second and third years (1958 and 1959) of the cooperative Aquatic-Life Resources project. Analysis of the 1957 population study data (secured by rotenone sampling in lock chambers and stream mouths along the Kentucky portion of the river) had indicated that the bulk of the standing population consisted of gizzard shad and the commercially important drum and catfishes. Creel census data and other sources of information lent support to this conclusion and indicated that the bulk of the commercial fishery catch probably consisted of drum and catfishes. In order to test the validity of this tentative conclusion and to determine whether drum and catfishes are of equal importance to sport fishing and commercial fishing interests, the survey here described was undertaken.

The data were obtained from licensed commercial fishermen, who agreed to keep daily catch records. These cooperators were contacted by their respective local Conservation Officers, who explained to them the reasons for, and the importance of, their services in this study of the fish population of the river. Only those fishermen who showed genuine interest and promised full cooperation were selected for participation. In 1958 there were 32 such cooperators and in 1959 there were 25.

II. METHODS

An attempt was made to secure at least one commercial fisherman cooperator from each Kentucky county bordering the river. This proved impossible inasmuch as certain counties, particularly some of those along the upper river, have no full-time fishermen because of pollution and a consequent lack of a market for Ohio River fish. Cooperators from 18 of Kentucky's 25 river-bordering counties were ultimately secured to keep records during 1958. The following year, 17 counties were represented by one or more cooperators.

Notebooks and an ample supply of daily catch record sheets were provided to each cooperator. Self-addressed postage-paid envelopes were also provided to either the C.O. or the cooperator, to help insure the prompt and steady return of completed catch records. The daily catch record sheets were simplified as much as was considered consistent with basic project needs. Although most commercial fishermen are "lumpers" in the truest sense of the word when it comes to fish nomenclature, those of certain localities along the river are confirmed "splitters". Most rivermen recognize the various species of catfish, but such species as river carpsucker, highfin carpsucker, and quillback are collectively termed "quillback" by the average commercial fisherman. The catch record sheets employed terminology considered familiar to the cooperators who would use them.

III. THE 1958 COMMERCIAL CATCH

The 32 commercial fishermen cooperators who kept catch records for the project during 1958 fished a total of 2,035 days, or an average of 64 days each. Fishing days reported by individuals ranged from 1 to 240. The cooperators were very lax in reporting the number of units of gear used per day, so unfortunately the data can not be expressed in the conventional unit of measurement for net catch data, the net-day. Nor were the cooperators conscientious about recording other than standard commercial fish species on the record sheets, although much emphasis had been placed on the desirability of keeping complete records for the project. The resultant data, while far from ideal in content or amount, are nevertheless gratifying and illuminating. Coupled with the 1959 cooperator catch records, they represent the best estimate to date concerning the catch composition and total poundage harvested annually by a representative group of Ohio River commercial fishermen.

For reporting purposes, the river was subdivided into three sections of approximately equal length which correspond with variations in the pollution load carried by the river. These sections are identical to those described and used in Section IV of this report, Creel Census Data.

Seven commercial fishermen cooperators reported their daily catch from the upper section of the river (218 miles from the West Virginia-Kentucky line to mile 535) during 1958. They logged an average of 32 fishing days each, totaling 227 days fished. Their catch numbered 7,601 fish and weighed a total of 21,794 pounds (Table 25). Carp made up the greatest weight, accounting for 32 per cent of the total poundage. Channel catfish was numerically the most abundant species in the harvest, comprising 34 per cent of the total catch. Species classed as commercial fishes comprised 85 per cent of all the fish taken in this stretch of the river. Their combined weight made up 91 per cent of the total catch.

Fourteen cooperators in the middle section of the river (207 miles from mile 535 to mile 742) kept daily catch records during 1958. They averaged 49 fishing days that year, a total of 689 fishing days. They caught 19,201 fish weighing 26,930 pounds. Channel catfish dominated the catch from the section, both in numerical abundance and in weight, making up 61 per cent of the total number and 43 per cent of the total weight. Combined, the commercial species comprised 98 per cent and 99 per cent, respectively, of the total number and poundage harvested. In Table 26 is presented a detailed breakdown of the species composition, showing the relative abundance and weight of each species entering the catch.

Eleven commercial fishermen recorded their daily catch from the lower section of the river in 1958. The cooperators in this section averaged 102 fishing days each, a considerably higher average than those achieved by the cooperators in the other two sections. A catch of 40,868 fish which weighed 72,609 pounds was reported for the year. As in the upper section, carp dominated the catch in poundage in the lower stretch of the river. However, this species made up only 22 per cent of the total weight from the lower section, as opposed to 32 per cent recorded in the upper section that same year. Channel catfish was again the most abundant fish in the catch, comprising more than 33 per cent of all fish harvested. The commercial fish species combined accounted for 99 per cent of both the total number and the total weight of the annual catch. Table 27 shows the composition of the catch from this section of the river during 1958.

IV. THE 1959 COMMERCIAL CATCH

Twenty-five commercial fishermen kept daily catch records for the project during 1959. These cooperators recorded the units of gear they used daily; consequently, their catch can be evaluated in terms of fish per net-day. Collectively, the cooperators logged 2,040 fishing days during the year, a total of 22,727 net-days. Most of the 1959 cooperators were the same fishermen who kept records during the previous year. Only 5 more fishing days were logged in 1959 than in the previous year, but there may have been a considerable difference in the total number of net-days fished. The amount of fishing effort varied from 8 days by one fisherman in the middle section to 242 days by one in the upper section. The average number of days fished per cooperator was 82. The net-days fished averaged 909 per fisherman. The total catch for the year was 51,755 fish weighing 73,600 pounds.

In the upper section of the river nine commercial fishermen, two more than in 1958, reported their daily catch in 1959. They averaged 81 fishing days, a total of 729 days, with an average of 538 net-days each, or a total of 4,842 net-days. They caught 10,970 fish weighing a total 14,327 pounds (Table 28). Channel catfish accounted for 62 per cent of the total number and 37 per cent of the total weight. Carp, the dominant species in the catch the year before, was second with only 7 per cent and 17 per cent, respectively, of the total number and weight. All commercial species combined comprised 94 per cent by number and 95 per cent by weight of the total catch in this area.

In the middle section of the river only seven cooperators, compared to 14 in 1958, kept catch records during 1959. They fished an average of 46 days each, a total of 325 fishing days, with an average of 168 net-days, for a total of 1,176 net-days. They caught 3,653 fish weighing 11,189 pounds. Channel catfish again dominated the catch both in numbers (58%) and in weight (45%). These values closely approximate those recorded for this species in this section during the previous year. Combined, the commercial fish species comprised 97 per cent and 96 per cent, respectively, of the total number and weight harvested. Table 29 gives detailed data on species composition.

In the lower section of the river nine cooperators, two fewer than in 1958, recorded their daily catch in 1959. They fished an average 110 days each (1,857 net-days) -- a considerably greater number of days than was fished by the cooperators in the two sections up-river. A total of 37,132 fish weighing 48,084 pounds was reported caught. Channel catfish topped the list, both in numbers (51%) and in weight (34%), with carp in second place. The commercial species combined accounted for 93 per cent of the total number and 94 per cent of the total weight, slightly less than in the previous year. Table 30 shows the species composition of the catch.

V. ANALYSIS

There is little doubt that the catfishes and freshwater drum are of equal and major importance to both sport and commercial fishermen in the Kentucky portion of the Ohio River. The commercial fishing survey shows that these species together comprised 71.9 per cent and 69.6 per cent of the catches of 1958 and 1959 respectively, while the creel census for the same years indicates that these species combined made up 72.4 per cent and 72.5 per cent of the sport fishermen's harvest. Carp comprised the bulk of the remaining commercial harvest.

Inasmuch as the number of active commercial fishermen on the Kentucky section of the Ohio River in 1958 has been determined in an independent study by James Carter of the Kentucky Department of Fish and Wildlife Resources, it is possible to estimate that the total catch was 2,000,000 pounds that year.

With more than 70 per cent of the catch composed of catfishes and drum with an average value of about 25 cents per pound, the estimated annual market value of these fishes was approximately $350,000. If it is assumed that the remainder of the catch has a value of 10 cents per pound, then the total estimated value of the 1958 commercial fishery was approximately $410,000.

AQUATIC-LIFE RESOURCES

OF THE OHIO RIVER

SECTION VI

TASTE AND ODOR QUALITIES

OF OHIO RIVER FISHES

by William M. Clay

During the summers of 1958 and 1959 tests were conducted to determine whether the palatability of certain food fishes of the Ohio River is impaired, as judged by residents of the valley who indicated a liking for freshwater fish as a table food. A further aim was to learn whether this potential food resource is being rejected to a significant extent for reasons of taste.

During the summer of 1958 the University of Louisville field crew was informed by the personnel stationed at Emsworth, Dashields, and Montgomery Locks below Pittsburgh that, in their opinion, the fish were unfit to eat because of a strong oily taste and odor, but that some residents of the area, usually persons of low economic status, ate carp caught below the dams.

Likewise, the personnel at Locks Nos. 8, 9, 10, 11, and 12 in upper West Virginia reported the fish unfit for table purposes.

Lock personnel at Winfield Lock at Winfield, W. Va., on the Kanawha River also reported that fishes caught in that vicinity were unfit for table use or were unpalatable, because of the strong oily or chemical taste and odor.

On the other hand, fishes from Mill Creek and Sandy Creek, Jackson County, W. Va., and apparently from all other streams of comparable size in West Virginia that are tributary to the Ohio River, are entirely palatable and are eagerly sought by local fishermen. It was noted that angling was particularly heavy at the mouths of most tributary streams in this area.

Channel catfish taken from Lock No. 17 near Reno, Ohio, Lock No. 18 near Constitution, Ohio, and Lock No. 19 near Parkersburg, W. Va. during the last week of June, 1958 were eaten by lock personnel and their acquaintances and were reported to be quite palatable and without any disagreeable taste or odor. Channel catfish and freshwater drum from Lock No. 22 near Ravenswood, W. Va., taken early in July, 1958, were eaten by local residents and others who reported them free of disagreeable tastes and odors.

However, fishes found near Lock No. 41 at Louisville, Kentucky, were tested by various members of the University of Louisville Biology Department and were found usually somewhat disagreeable in taste and odor. Considerable variation sometimes exists among different specimens taken at the same time and place.

During the summer of 1959 a procedure was followed in which recipients of fishes offered by the ORSANCO field crew were asked to fill out and return a questionnaire, a copy of which appears as Table 31 in Appendix III. During the period from June 10 to July 29, 1959, 16 replies were received which expressed evaluations by 54 persons. These findings are summarized below.

At Captina Creek, Ohio, near Powhatan Point, channel catfish obtained on July 28, 1959, were reported upon by six tasters, all of whom classified the fish as being of very poor quality and having a strong oily taste.

In the Ohio River near Ashland, Ky., between river miles 322 and 324, channel catfishes collected on June 5 and 6, 1959, were reported upon in two replies, involving seven tasters. Three regarded the fishes as being of average quality; four of poor quality. On one reply it was noted that the fish had the flavor of a sweet oil and the odor of shoe dye. The other reply indicated that the fish were probably all right but that the tasters were influenced by thoughts that the fish might not be good.

From McAlpine Lock at Louisville, several channel catfish and one flathead catfish collected on June 4, 1959, were distributed to several recipients. Nine replies, representing a total of 30 tasters, were received in the period of June 10 to 14. Six classified the fish as good, four as average, and 20 as poor. Comments varied: excellent--no oily or other unpleasant taste; good; excellent taste; strong metallic taste; gasoline taste; oily taste; inedible; petroleum-oily flavor; one fish poor but edible, one inedible.

A later collection of channel catfish and drum taken in the Louisville area during the first week of July afforded three replies from seven tasters. Three classified the fish as very good, two found the catfish average and the drum poor; and two classified both the drum and catfish as poor. One commented that the drum was of a more oily flavor and of a generally flatter taste. Another commented that the drum meat was of a nice, flaky texture but had an oily taste.

Drum from the West Point area (about Mile 620) collected June 5 and 6, 1959, were reported upon in one reply representing four tasters, all of whom rated the fish as good.

Analysis of the data gathered in this limited survey discloses no significant difference between the relative palatability of channel catfish and drum, nor between refrigeration and freezing as means of preservation. Although it is well known that drum do not keep well and should be eaten fresh, it seems probable that in this survey these factors were outweighed or obscured by the marked degree to which the flesh was in some instances impaired by environmental influences.

Mr. John Williams was informed by a commercial fisherman in the Leavenworth, Ind., area on June 28, 1960, that the fish in that area of the Ohio River are no longer edible, due to a taste resembling "slaked carbide", that the market for dressed fish is gone, and that the only remaining market is for live fish for pay ponds. This condition developed, he said, subsequent to the establishment of a large chemical plant near Brandenburg. This fisherman said a "green paint-like material" (probably a blue-green alga) had appeared on boats in that area during the last two years.

It may be noted that, as would be expected, the flavor and odor of fish flesh is most impaired in those areas immediately subject to industrial or municipal pollution. For this reason, much of the upper third of the Ohio River is not suitable at present as a source of table fish. On the other hand, the lower half or more of the river is considerably used for this purpose, and it has been the personal observation of the writer that restaurants in the lower end of the Ohio valley advertise that their catfish are from the Ohio River. Commercial fishermen in the vicinity of Louisville and between Louisville and Cincinnati have related to the writer that their catches sometimes are of impaired flavor. It is apparent that the middle third of the river contains zones in which commercial fishing, for this reason, is not practicable. Most of the upper third is, of course, not suited for commercial fishing at the present time.

AQUATIC-LIFE RESOURCES

OF THE OHIO RIVER

SECTION VII

GENERAL CONSIDERATIONS AND SUMMARY

by Bernard T. Carter and William M. Clay

Geologists have shown that the Ohio River is a compound stream, with a venerable and complex history. To the ancient Ohio, which is represented by something less than the lower half of the present river, portions of other discrete stream systems were added when Pleistocene glaciers blocked their lower courses and diverted their waters into the Ohio River basin.

The composition of the fish fauna of the Ohio River has thus been determined by former as well as present-day conditions. In early post-Pleistocene times this fauna must have included many cold-water species, most of which have now retreated to higher latitudes. It may be logically supposed that when the Ohio received large quantities of melt-water from snow fields and ice fields, such fishes as ciscoes, grayling, trout, and burbot were present. With climatic amelioration, warm-water species, which had ready access from the south, invaded the Ohio to the extent that environmental and biological conditions permitted. Species or species groups with predominantly warm-water affinities include the black basses, gizzard shad, threadfin shad, skipjack herring, and alligator gar. Some species have had more direct access from the Atlantic drainage by way of connections with the Great Lakes or their outlets. Certain plains species, particularly of chubs and minnows, have made their way from the western portions of the Mississippi drainage into the Ohio basin.

A few species are essentially endemic to the Ohio valley. The Ohio lamprey, Ichthyomyzon bdellium, occurs only in the Ohio and its largest tributaries. Another is the Ohio valley sub-species of the muskellunge, Esox masquinongy ohiensis. The Ohio shad, Alosa ohiensis, if a valid species, is another. Several darters, shiners, and chubs, predominantly creek species, are endemic to the Ohio basin but are not treated in this report inasmuch as they do not occur in the Ohio River proper.

The earliest accounts of the river indicate that it abounded in fine food fishes. Excerpts from these accounts are included in the foregoing section on the history of the river, and the topic needs no further treatment at this point.

By the middle of the nineteenth century, agricultural practices, deforestation, and the establishment of communities along the river began to produce at least localized effects. Increased siltation probably began about this time, and municipal wastes led to chemical and biological changes in the river proper and in the mouths of creeks near the settlements. The erection of dams led to further changes. In 1855 the first dam was constructed five miles below Pittsburgh. By 1911, eleven more dams were built between Pittsburgh and Parkersburg, W. Va. In 1929, the system had been completed and was capable of maintaining a nine-foot pool stage throughout the entire river. By this means the river was converted from a series of pools and semi-rapids to a series of pools only, the single exception being the Falls of the Ohio, a rapids below McAlpine Dam at Louisville, and even a portion of this rapids was submerged beneath the waters of the Louisville pool. The elimination of the rapids probably depressed those species which either breed or feed in these shallow swiftly-flowing waters. It is likely also that the dams have had a depressing effect upon anadromous or potamodromous species, for while the dams are not strictly impassable barriers inasmuch as fish can lock through along with boats or move readily up and down the stream during times of high water when portions of the dams are lowered, it is certain that the dams impede such movements during periods of low flow, and when these coincide with pre-breeding migration, reproduction may be more or less curtailed. It is likely that suckers are especially susceptible to this factor.

No industry has had a greater effect than coal mining upon the fishes of the Ohio basin. This, and the associated steel industry, had a phenomenal growth during the last half of the nineteenth century, and the expansion continued through the first half of the twentieth century. One of the major existing problems is that of abatement of acid wastes from abandoned coal mines. In some of the tributaries of the Ohio the pH is depressed to a point at which fish can not survive.

Chemical industries have made spectacular growth during the twentieth century and in some instances have led to severe impairment of the flavor and odor of fish flesh. In other instances, the intentional or accidental discharge of certain industrial wastes into the river has led to extensive and frequent fish kills.

It should be emphasized again that siltation of portions of the Ohio and its tributaries has had both direct and indirect effects upon the fish fauna. A covering of silt, even though thin, over an otherwise gravelly or sandy bottom, may destroy the conditions necessary for reproduction in certain species, and at the same time, may have an adverse effect upon bottom organisms used as food supply by various fishes. The same silty conditions and associated turbid waters are more favorable for certain other species, most of which, unfortunately, are in the rough fish category. Among the many species regarded by Trautman (1957) as declining are the lake sturgeon, shovel-nosed sturgeon, blue catfish, walleye, yellow bullhead, paddlefish, and muskellunge, while those which are increasing include the goldeye, carp, and gizzard shad.

In order to obtain information on the prevailing physical, chemical and biological conditions of the river, a limited limnological survey was carried out as a secondary part of the Aquatic-Life Resources project. Although a thorough survey was not possible within the prescribed scope of the project, a reconnaissance or exploratory survey seemed to be highly desirable. Accordingly, work of this character was performed during each of the three years of the study.

Despite the imposed limitations, the limnological phase of the Aquatic-Life study has yielded a body of information of importance in understanding the river and has disclosed special problems which should be attacked in the future.

A general picture of the river resulted from a comparison which was made during the summer of 1959 of seven representative portions of the river. This study, in which more than 1,600 physical and chemical evaluations and 210 plankton analyses were made, indicated that the upper river from Pittsburgh to below Wheeling was strongly acid in certain places, high in $CaCO_3$, and relatively transparent. Dissolved oxygen was often critically low. An algal bloom (described in this paper as having a count greater than 500 cells per milliliter) occurred in the lower end of the Allegheny in 1959.

The most highly polluted region of those studied was that including Huntington and Ashland, where high copper and iron values, accompanied by low pH and low dissolved oxygen, were able to destroy a rich plankton crop as it moved downstream into this area.

From Cincinnati to the mouth of the Ohio River the greater distances between large municipal and industrial areas provide long stretches that are relatively free from intensive pollution.

The plankton of the river develops mostly within the river; little is supplied from tributaries or from flood-plain lakes and ponds. Diatoms are the dominant group of phytoplankters, with rotifers and cladocerans dominating the zooplankton.

Several phytoplankton blooms, usually accompanied by unpalatable tastes and odors of the water, developed in several parts of the river during the course of the study. Verbal reports from water users indicate that plankton blooms have become more frequent in recent years and appear earlier in the season than previously.

A molluscan fauna was present in the river from about the 300-mile point (Huntington area) to Leavenworth and probably it continues to the Mississippi, but no living shells were found in the upper 100 miles of the river. Clam shells for buttons once constituted an important industry in the Ohio valley, but with changed biological conditions decreasing the abundance of mussels and with greater use of other materials for buttons, the industry has declined in recent years.

Other members of the bottom fauna include larvae of midges and other insects, some of which, such as the chironomid Tendipes, are important dietary items for young catfish, drum, and such small bottom-feeding fishes as the silver chub.

The study of the fish population of the Ohio River and the mouths of its tributaries was the major phase of the Aquatic-Life Resources project. Sampling was carried out during the entire three years of the project and extended over the entire length of the river. Of the 341 collections, 225 were made with rotenone, 50 with nets, 26 with seines, 20 with electric shocker, 18 with otter trawls, and 2 with pole and line. Of these collections, 248 were made in the main stream of the Ohio River, the remainder in tributaries; 124 were made in lock chambers of the main stream, 12 in lock chambers of tributary streams. Each main stream lock chamber was sampled at least once, and some several times.

A total of 130 kinds of fish were taken, comprising 741,438 individuals with a total weight of 32,679 pounds.

The ten most abundant species of fish in the population samples were, in order of abundance, emerald shiner, gizzard shad, drum, mimic shiner, channel catfish, silver chub, black bullhead, threadfin shad, blue catfish, and sand shiner. The ten species which contributed the greatest total weight in the samples were gizzard shad, carp, channel catfish, drum, emerald shiner, skipjack herring, flathead catfish, blue catfish, black bullhead, and river carpsucker, respectively.

Therefore, of the ten most abundant species, six are forage fishes, three are species sought by both sport and commercial fishermen, and one species, the black bullhead, is of interest primarily to the angler. Of those ten species contributing the greatest weight, two are forage fishes, five are of interest to both sport and commercial fishermen, one, the black bullhead, is of interest only to the angler, and two, skipjack and river carpsucker, are not of significant interest to either group nor do they play an important role as forage fishes.

None of the game and pan fishes rank high either in weight or in numbers in these samples, a finding which is substantiated by the creel census data.

As might be expected, the species composition varied somewhat throughout the river. In the upper third of the river the most abundant species taken were emerald shiner, mimic shiner, sand shiner, black bullhead, and channel catfish. In the middle section the leading species were emerald shiner, channel catfish, gizzard shad, drum, and silver chub, with the blue catfish abundant downstream; the mimic shiner, sand shiner, and black bullhead were not abundant in this section. In the lower third the drum, gizzard shad, blue catfish, channel catfish, and threadfin predominated with the emerald shiner occurring in small numbers.

Other species occurring predominantly in the upper river and rare in or absent from the lower river were troutperch, walleye, white sucker, and yellow perch. The blue sucker, paddlefish, bowfin, sauger, rock sturgeon, and round flier occurred in moderate numbers in the lower river and were absent from the upper river.

The fishes collected from the lock chambers of the Ohio River amounted to an average of 155 pounds per surface acre. In estimating the standing crop of fish in the river, it must be borne in mind that the pickup of fish in a chamber is always incomplete, and that the density of the population in the chamber may be less or greater than that of the river. If it is assumed that the mean density of the population in the chambers is the same as that of the river, and that only 50 per cent of the fish in the chamber are picked up, then the estimated standing crop in the river is approximately 300 pounds per acre.

During each of the three years of the project a study was conducted to determine the success of sport fishermen in the Kentucky portion of the Ohio River and the overall fishing pressure supported by this portion of the river. From interviews with 7,248 fishermen it was determined that catfishes and drum comprised 70 per cent or more of the sport fishing catch. Catfishes were more abundant in the creels in the upper and middle sections of the Kentucky portion, and drum were more abundant in the lower section. Other fishes contributing substantially to the catch were, in order of abundance, carp in all three sections, sunfishes in the upper section, white bass, crappies, and black basses in the middle and lower sections.

The rate of success ranged from a low of 0.5 fish per hour in the middle section to a high of 1.4 fish per hour in the lower section. During all three years of the study the rate of catch was consistently higher in the lower section of the river. In all sections the average length of the fishes reported was approximately one foot.

Disregarding the bank fishermen of the north shore, who were not sampled, but including all boat fishermen, almost 80 per cent of the anglers were Kentucky residents; about 90 per cent of these were male. More than 90 per cent were fishing with live or prepared baits, a fact which probably accounts in part for the relatively small number of game fishes in the catch. From the total counts of fishermen, both from air and by boat, it was estimated that the Kentucky portion of the river supported an average fishing pressure of 1,511 angler trips per day, or 2.3 fishermen per mile.

During the period of April through October 1959, 287,000 anglers caught 746,000 fish weighing 522,000 pounds. The market value of these fish amounted to about $130,600. The fact that the estimated average cost to the fishermen of each fish caught was more than one dollar, or about $1.30 a pound, which is about five times the market value of the food, indicates that the recreational value of this sport far exceeds the intrinsic food value of the fish, and points up the fallacy of attempting to compare on a dollar basis the relative values of this recreational activity with commercial uses of the river.

From a commercial fishing survey conducted in 1958 and 1959 it was determined that the total harvest in 1958 in the Kentucky portion of the river amounted to about 2,000,000 pounds, valued at $410,000. Catfishes and drum comprised about 70 per cent of the catch and accounted for $350,000 of the total value.

It is noteworthy that catfishes and drum also comprise about 70 per cent of the sport fishing catch. The resulting competition between commercial and sport fishermen is, however, negligible because of the smallness of the total harvest in proportion to the standing crop.

It may then in conclusion be noted that while the present attributes of the river stem from many factors of which some are of geological antiquity, most of the attributes which are of concern in river management are the result of human activities. It is these human modifications which account for the sharpest contrasts within the chemistry, the biology, and even the regimen of the river.

It is encouraging to note that with local exceptions, the Ohio River fishery has improved in recent years, according to the reports of commercial fishermen. This improvement has coincided largely with the establishment of municipal sewage treatment plants and with greater attention given to the treatment of industrial wastes before their discharge into the river. It appears thus to be demonstrated that the same care which the river deserves in order to maintain it properly for human and industrial uses renders it at least moderately fit for fish life and is the hope upon which future sport and commercial fisheries programs must be founded.

AQUATIC-LIFE RESOURCES

OF THE OHIO RIVER

APPENDIX I

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AQUATIC-LIFE RESOURCES

OF THE OHIO RIVER

APPENDIX II

SPECIES OF FISHES TAKEN IN THE FISH POPULATION STUDIES

This is a list of species of fishes taken from the Ohio River during the investigations of the fish population of the Ohio River made from May, 1957 to June, 1960. The data include the number of collections in which each species was represented, the number of individuals taken in all collections, and the total weight in pounds of all fishes of each species taken.

The list follows the sequence and nomenclature of the American Fisheries Society Guide, A List of Common and Scientific Names of Fishes from the United States and Canada, Second Edition, 1960, with the exception of two sub-species and, of course, the hybrids, which are not recognized in the list.

Scientific Name	Common Name	No. of collections in which species occurs	Number taken in all collections	Total weight in pounds
PETROMYZONTIDAE				
Ichthyomyzon bdellium (Jordan)	Ohio lamprey	3	7	0.32
ACIPENSERIDAE				
Scaphirhynchus platorynchus (Rafinesque)	shovelnose sturgeon	1	1	1.02
POLYODONTIDAE				
Polyodon spathula (Walbaum)	paddlefish	17	38	109.82
LEPISOSTEIDAE				
Lepisosteus osseus (L.)	longnose gar	67	218	72.53
Lepisosteus platostomus Rafinesque	shortnose gar	31	105	57.40
AMIIDAE				
Amia calva L.	bowfin	5	22	80.81

Scientific Name	Common Name	No. of collections in which species occurs	Number taken in all collections	Total weight in pounds
CLUPEIDAE				
Alosa chrysochloris (Rafinesque)	skipjack herring	147	3,550	1,136.63
Dorosoma cepedianum (LeSueur)	gizzard shad	220	107,165	14,583.68
Dorosoma petenense (Günther)	threadfin shad	34	8,003	132.36
SALMONIDAE				
Salmo trutta L.	brown trout	1	1	0.20
HIODONTIDAE				
Hiodon alosoides (Rafinesque)	goldeye	57	205	63.13
Hiodon tergisus LeSueur	mooneye	29	83	10.09
ESOCIDAE				
Esox americanus vermiculatus LeSueur	grass pickerel	6	7	0.45
Esox masquinongy ohioensis Kirtland	muskellunge	3	3	10.19
CYPRINIDAE				
Campostoma anomalum (Rafinesque)	stoneroller	26	577	3.87
Carassius auratus (L.)	goldfish	27	285	77.36
Chrosomus erythrogaster (Rafinesque)	southern redbelly dace	1	1	0.01
Cyprinus carpio L.	carp	184	2,886	3,574.78
Carassius auratus x *Cyprinus carpio*	goldfish x carp hybrid	5	8	3.70

Scientific Name CYPRINIDAE (Continued)	Common Name	No. of collections in which species occurs	Number taken in all collections	Total weight in pounds
Dionda nubila (Forbes)	Ozark minnow	1	29	0.05
Ericymba buccata Cope	silverjaw minnow	9	17	0.09
Hybognathus hayi Jordan	cypress minnow	1	2	0.01
Hybognathus nuchalis Agassiz	silvery minnow	20	1,381	8.33
Hybopsis aestivalis (Girard)	speckled chub	7	82	0.15
Hybopsis amblops (Rafinesque)	bigeye chub	4	36	0.09
Hybopsis biguttata (Kirtland)	hornyhead chub	2	12	0.08
Hybopsis dissimilis (Kirtland)	streamline chub	3	16	0.05
Hybopsis micropogon (Cope)	river chub	3	39	0.75
Hybopsis storeriana (Kirtland)	silver chub	176	11,789	162.21
Notemigonus crysoleucas (Mitchill)	golden shiner	22	905	41.06
Notropis atherinoides Rafinesque	emerald shiner	215	428,463	1,222.63
Notropis blennius (Girard)	river shiner	73	1,416	5.11
Notropis buchanani Meek	ghost shiner	23	889	1.41
Notropis cornutus (Mitchill)	common shiner	37	675	7.03
Notropis fumeus Evermann	ribbon shiner	1	1	0.01
Notropis galacturus (Cope)	whitetail shiner	1	3	0.01
Notropis hudsonius (Clinton)	spottail shiner	1	1	0.01
Notropis illecebrosus (Girard)	silverband shiner	7	507	2.35
Notropis lutrensis (Baird and Girard)	red shiner	1	1	0.01
Notropis rubellus (Agassiz)	rosyface shiner	6	332	0.83
Notropis spilopterus (Cope)	spotfin shiner	43	587	3.06

Scientific Name	Common Name	No. of collections in which species occurs	Number taken in all collections	Total weight in pounds
CYPRINIDAE (Continued)				
Notropis stramineus (Cope)	sand shiner	46	3,633	9.66
Notropis texanus (Girard)	weed shiner	1	1	0.01
Notropis volucellus (Cope)	mimic shiner	99	50,241	103.72
Notropis whipplei (Girard)	steelcolor shiner	9	41	0.39
Opsopoeodus emiliae Hay	pugnose minnow	1	4	0.01
Phenacobius mirabilis (Girard)	suckermouth minnow	10	17	0.07
Pimephales notatus (Rafinesque)	bluntnose minnow	73	2,023	6.85
Pimephales promelas Rafinesque	fathead minnow	8	9	0.06
Pimephales vigilax (Baird and Girard)	bullhead minnow	5	14	0.08
Rhinichthys atratulus (Hermann)	blacknose dace	3	5	0.04
Semotilus atromaculatus (Mitchill)	creek chub	20	344	2.04
CATOSTOMIDAE				
Carpiodes carpio (Rafinesque)	river carpsucker	126	1,157	469.80
Carpiodes cyprinus (LeSueur)	quillback	31	171	125.34
Carpiodes forbesi Hubbs	plains carpsucker	2	2	3.00
Carpiodes velifer (Rafinesque)	highfin carpsucker	7	16	9.18
Catostomus commersoni (Lacépède)	white sucker	42	627	93.34
Cycleptus elongatus (LeSueur)	blue sucker	5	7	25.65
Erimyzon oblongus (Mitchill)	creek chubsucker	2	5	0.02
Erimyzon sucetta (Lacépède)	lake chubsucker	2	3	0.04
Hypentelium nigricans (LeSueur)	northern hog sucker	15	124	11.35
Ictiobus bubalus (Rafinesque)	smallmouth buffalo	83	504	446.39

Scientific Name	Common Name	No. of collections in which species occurs	Number taken in all collections	Total weight in pounds
CATOSTOMIDAE (Continued)				
Ictiobus cyprinellus (Valenciennes)	bigmouth buffalo	23	155	113.82
Ictiobus niger (Rafinesque)	black buffalo	5	7	26.07
Minytrema melanops (Rafinesque)	spotted sucker	55	609	259.21
Moxostoma anisurum (Rafinesque)	silver redhorse	3	11	19.89
Moxostoma breviceps (Cope)	shorthead redhorse	9	32	5.75
Moxostoma carinatum (Cope)	river redhorse	4	40	14.47
Moxostoma duquesnei (LeSueur)	black redhorse	11	79	21.00
Moxostoma erythrurum (Rafinesque)	golden redhorse	39	744	169.09
Moxostoma macrolepidotum (LeSueur)	northern redhorse	1	1	0.01
	unidentified redhorse	11	84	50.17
ICTALURIDAE				
Ictalurus furcatus (LeSueur)	blue catfish	67	6,473	586.90
Ictalurus melas (Rafinesque)	black bullhead	77	8,878	563.49
Ictalurus natalis (LeSueur)	yellow bullhead	35	121	9.09
Ictalurus nebulosus (LeSueur)	brown bullhead	18	443	45.52
Ictalurus punctatus (Rafinesque)	channel catfish	228	22,722	3,556.86
Noturus eleutherus Jordan	mountain madtom	7	56	0.25
Noturus exilis Nelson	slender madtom	1	2	0.02
Noturus flavus Rafinesque	stonecat	5	34	1.32
Noturus gyrinus (Mitchill)	tadpole madtom	18	248	1.15
Noturus miurus Jordan	brindled madtom	12	78	0.51
Noturus nocturnus Jordan and Gilbert	freckled madtom	1	5	0.01

Scientific Name	Common Name	No. of collections in which species occurs	Number taken in all collections	Total weight in pounds
ICTALURIDAE (Continued)				
	unidentified madtoms	18	115	0.65
Pylodictis olivaris (Rafinesque)	flathead catfish	169	1,619	856.86
ANGUILLIDAE				
Anguilla rostrata (LeSueur)	American eel	11	17	7.31
CYPRINODONTIDAE				
Fundulus diaphanus diaphanus	eastern banded killifish	1	1	0.01
Fundulus diaphanus menona	western banded killifish	4	28	0.40
Fundulus notatus (Rafinesque)	blackstripe topminnow	6	119	0.34
Fundulus olivaceus (Storer)	blackspotted topminnow	1	1	0.01
POECILIIDAE				
Gambusia affinis (Baird and Girard)	mosquitofish	5	94	0.11
PERCOPSIDAE				
Percopsis omiscomaycus (Walbaum)	troutperch	16	1,083	5.47
APHREDODERIDAE				
Aphredoderus sayanus (Gilliams)	pirate perch	10	23	0.26
SERRANIDAE				
Roccus chrysops (Rafinesque)	white bass	29	134	16.14
Roccus mississippiensis (Jordan and Eigenmann)	yellow bass	4	26	2.21

Scientific Name	Common Name	No. of collections in which species occurs	Number taken in all collections	Total weight in pounds
CENTRARCHIDAE				
Ambloplites rupestris (Rafinesque)	rock bass	22	102	8.67
Centrarchus macropterus (Lacépède)	flier	2	3	0.10
Chaenobryttus gulosus (Cuvier)	warmouth	50	454	19.31
Lepomis cyanellus Rafinesque	green sunfish	92	752	10.36
Lepomis gibbosus (L.)	pumpkinseed	28	368	9.76
Lepomis humilis (Girard)	orangespotted sunfish	29	265	2.86
Lepomis macrochirus Rafinesque	bluegill	146	3,532	102.99
Lepomis megalotis (Rafinesque)	longear sunfish	107	2,545	87.52
Lepomis microlophus (Günther)	redear sunfish	8	17	0.49
Micropterus dolomieui Lacépède	smallmouth bass	14	134	16.18
Micropterus punctulatus (Rafinesque)	spotted bass	75	251	48.89
Micropterus salmoides (Lacépède)	largemouth bass	62	258	127.20
Pomoxis annularis Rafinesque	white crappie	120	1,243	116.98
Pomoxis nigromaculatus (LeSueur)	black crappie	86	395	54.58
PERCIDAE				
Etheostoma asprigene (Forbes)	mud darter	3	9	0.04
Etheostoma blennioides Rafinesque	greenside darter	8	63	0.13
Etheostoma caeruleum Storer	rainbow darter	7	40	0.12
Etheostoma flabellare Rafinesque	fantail darter	12	71	0.26
Etheostoma gracile (Girard)	slough darter	3	27	0.05
Etheostoma kennicotti (Putnam)	stripetail darter	3	21	0.06

Scientific Name	Common Name	No. of collections in which species occurs	Number taken in all collections	Total weight in pounds
PERCIDAE (Continued)				
Etheostoma nigrum Rafinesque	johnny darter	13	76	0.17
Etheostoma proeliare (Hay)	cypress darter	1	2	0.01
Etheostoma spectabile (Agassiz)	orangethroat darter	1	4	0.01
Etheostoma squamiceps Jordan	spottail darter	2	4	0.02
Etheostoma zonale (Cope)	banded darter	2	3	0.01
Perca flavescens (Mitchill)	yellow perch	9	27	1.66
Percina caprodes (Rafinesque)	logperch	25	226	2.53
Percina macrocephala (Cope)	longhead darter	3	4	0.04
Percina maculata (Girard)	blackside darter	7	27	0.13
Percina phoxocephala (Nelson)	slenderhead darter	1	2	0.01
Percina sciera (Swain)	dusky darter	2	4	0.02
Percina shumardi (Girard)	river darter	2	2	0.02
Stizostedion canadense (Smith)	sauger	33	106	55.97
Stizostedion vitreum vitreum (Mitchill)	walleye	11	29	18.45
SCIAENIDAE				
Aplodinotus grunniens Rafinesque	freshwater drum	193	50,607	2,949.48
COTTIDAE				
Cottus bairdi Girard	mottled sculpin	1	1	0.01
Cottus carolinae (Gill)	banded sculpin	1	2	0.05
ATHERINIDAE				
Labidesthes sicculus (Cope)	brook silverside	1	10	0.03
TOTAL: 23 families, 130 species (plus one hybrid, two sub-species, and four groups of unidentified fishes)		341	741,438	32,678.81

AQUATIC-LIFE RESOURCES

OF THE OHIO RIVER

APPENDIX III

TABLES

Table 1. Comparative maximum-minimum values of physical-chemical measurements made in the seven regions of the Ohio River during the summer of 1959.

REGION	I	II	III	IV	V	VI	VII
MAXIMUM VALUES							
Temperature (°C.)	28.0	29.6	30.0	31.0	29.0	29.0	30.0
Secchi Readings (inches)	28.0	48.0	36.0	36.0	50.0	40.0	30.0
Dissolved Oxygen (mg/L)	5.7	8.3	11.1	11.1	7.4	8.8	5.7
Dissolved Oxygen (% Saturation)	78.0	114.0	151.0	152.0	99.0	117.0	78.0
pH	7.1	7.6	7.7	8.3	7.7	7.8	7.4
M. O. Alkalinity (mg/L $CaCO_3$)	25.0	34.0	29.0	58.0	85.0	93.0	64.0
Phenolphthalein Alkalinity (mg/L $CaCO_3$)	0.0	0.0	0.0	7.9	0.0	0.0	0.0
Free Carbon Dioxide (mg/L)	14.6	7.3	11.2	12.9	5.5	7.3	11.2
Nitrates (mg/L)	0.7	1.0	2.0	2.0	1.8	2.6	0.7
Phosphates (mg/L)	0.5	0.4	0.3	5.0	1.4	1.0	0.5
MINIMUM VALUES							
Temperature (°C.)	28.0	23.0	27.0	27.0	28.0	27.0	29.0
Secchi Readings (inches)	21.0	26.0	18.0	14.0	16.0	10.0	20.0
Dissolved Oxygen (mg/L)	1.7	5.2	6.6	2.5	4.7	4.9	5.3
Dissolved Oxygen (% Saturation)	22.0	64.0	86.0	32.0	61.0	63.0	70.0
pH	6.3	6.8	6.6	6.8	7.3	7.3	7.0
M. O. Alkalinity (mg/L $CaCO_3$)	15.0	24.0	23.0	42.0	57.0	76.0	58.0
Phenolphthalein Alkalinity (mg/L $CaCO_3$)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Free Carbon Dioxide (mg/L)	4.8	1.6	1.1	0.0	3.2	2.8	4.9
Nitrates (mg/L)	0.5	0.5	1.2	0.8	1.2	1.0	0.4
Phosphates (mg/L)	0.3	0.1	0.3	0.2	0.5	0.5	0.3

Table 2. Dissolved oxygen expressed in milligrams per liter between Mile 307.2 and Mile 326.0 in the Ohio River during June and July 1959.

MILE	DATE	DISSOLVED OXYGEN (mg/L)
307.2	7/31	2.5
311.0	7/31	3.2
316.5	7/31	2.9
317.1	7/14	5.2
322.0	6/18	5.4
322.0	7/31	3.4
326.0	7/31	3.9

Table 3. Phytoplankton genera represented in each of the seven regions of the Ohio River during the summer of 1959. Those reported with an X were those genera found in at least three samples.

PHYTOPLANKTON	REGIONS						
	I	II	III	IV	V	VI	VII
Melosira	X	X	X	X	X	X	X
Anabaena	X	X	X	X		X	X
Pleodorina	X	X	X	X		X	X
Actinastrum	X	X	X	X	X	X	
Synedra	X	X	X	X	X	X	
Staurastrum	X	X	X	X	X	X	
Scenedesmus	X	X	X	X	X	X	
Fragilaria	X	X	X	X	X	X	
Pediastrum	X	X	X	X	X	X	
Selenastrum	X	X	X	X	X	X	
Spirogyra	X	X	X	X	X	X	
Oscillatoria	X	X	X	X	X	X	
Oocystis	X	X	X	X	X	X	
Dictyosphaerium	X	X	X	X	X	X	
Anacystis	X	X	X	X		X	
Cosmarium	X	X		X	X	X	
Closterium	X	X		X	X	X	
Crucigenia	X		X	X	X	X	
Nitzchia	X			X	X	X	
Golenkinia	X			X	X		
Tetraspora	X	X					
Gonium		X					
Asterionella			X	X	X	X	
Tabellaria					X	X	X
Pandorina					X	X	X
Micractinium					X	X	X

Other organisms of sporadic occurrence:

Tribonema
Kirchneriella
Phacus
Peranema
Agmenelium
Dimorphococcus
Gloeocystis
Gomphlosphaeria
Uroglenopsis
Microspora
Oedogonium
Euglena
Ulothrix
Westella
Tetraedron
Dinobryon
Polyedriopsis
Schroederia
Glenodinium
Lyngbya
Cymbella
Mougeotia
Pinnularia
Ceratium

Table 4. Zooplankton collected from two contiguous pools between Mile 596 and Mile 618 on the Ohio River from October through December 1958. Relative abundance indicated by: A--abundant, C--common, and U--uncommon.

POOLS	2	1	1	2	2	2	1	2	1
Dates	10/4	10/10	10/17	10/18	10/24	10/31	11/19	12/5	12/17
PROTOZOA									
Codonella		C							
Carchesium				C					
Vorticella								C	A
Scyphidia								C	
Stentor				C					
Trachelius				C					
PORIFERA									
Spongilia	C								
COELENTERATA									
Hydra americana				A		U			
ENDOPROCTA									
Urnatella gracilis	A		C	C					
ROTIFERA									
Limnias				U					
Keratella cochlearis	C	C	A	U	A	A	C	A	C
Keratella vulgara		U			U		U		
Brachionus quadridentata				U					
Brachionus furculata						U			
Brachionus calyciflorus	C	C	A	U	A	A	A		U
Brachionus budapestinensis							U		
Brachionus sp.									U
Platias patulus					U		U		
Trichocera	U	U		U	U				
Euchlanis									U
Polyarthra trigla	A	U	C	C	A	C			
Kellicottia longispina									C
Monostyla					U				
Rotaria		U							
Lepadella		U							
Lecane		U							
Synchaeta						U			
ARTHROPODA									
CLADOCERA									
Chydorus sphaericus		U			U	U	U		
Alona guttata								U	
Simocephalus							U		
Bosmina longirostris	C	A	A	C	C	A	C	C	C
Daphnia longispina					U				
Pleuroxis striatus						U			
COPEPODA									
Cyclops vernalis	C	A	A		C	A	C	C	
Naupliar stages	C	A	A	U		A	C	C	C
Canthocamptus				C					

Table 5. Phytoplankton organisms collected in the Ohio River at Mile 602.1 on July 31 and September 20, 1958.

July 31, 1958

GREEN ALGAE	BLUE-GREEN ALGAE	DIATOMS
Gonium	Oscillatoria	Melosira
Carteria	Anabaena	Synedra
Pediastrum (two species)	Anacystis	Fragillaria
Scenedesmus (two species)		
Coelastrum		
Sphaerocystis		
Westella		
Dictyosphaerium		
Closterium		
Oocystis		
Ankistrodesmus		

September 20, 1958

GREEN ALGAE	BLUE-GREEN ALGAE	DIATOMS
Pediastrum	Anacystis	Asterionella
Golenkinia	Chroococcus	Synedra
Closterium	Lyngbya	Melosira
Staurastrum		Fragillaria
Scenedesmus		

YELLOW-GREEN ALGAE

Ceratium

Table 6. Net plankton collected in 1958 at a station in the Ohio River between the Louisville Municipal Boat Harbor and Twelve Mile Island, except November 5* and 19*, which are both from near the mouth of Silver Creek, Indiana. Relative abundance indicated by: A--abundant, C--common, and U--uncommon.

	October				November						December		
ALGAL SPECIES	10	17	24	31	4	5*	13	17	19	19*	4	5	17
DIATOMS													
Asterionella formosa	A	A	A	A	A	U	A	A	A	C	C	U	
Melosira sp.	A	A	A	A	A	A	A	A	A	A	A	C	C
Synedra ulna	A	A	A	A	A	C	A	A	A	A	C	U	U
Fragillaria sp.	C		C	C	C	C	U	C	C		U		U
Pleurosigma sp.			U								U		
Tabellaria fenestrata	U	C					C	U	U				
Navicula	U	U	U	U	U	U	U	U	U		U	U	U
Nitschia sigmoides			U										U
Bacillaria paradoxa			U	C							U		U
OTHER DIATOMS	C	U	C	U	U	U	U	U	U	U	U		
DESMIDS													
Closterium moniliferum		U	U								U		U
Cosmarium sp.			U								U		
Staurastrum		U	U					U	U				
CHLOROCOCCALES													
Actinastrum hantschii		C			C	C	C	C	C		U		
Ankistrodesmus falcatus					U								
Coelastrum microporum					U								
Coelastrum recticulatum			U		U								
Crucigenia irregularis							U	C	U				
Dictyosphaerium pulchellum					C		A	A	A		U		
Dimorphococcus lunatus								U					
Gloeocystis gigas							U						
Golenkinia radiata	C						C	A					
Kirchneriella obesa								U	U				
Lagerheimia droescheri							U						
Micractinium pusillum							A	C	A				
Nephrocytium aghardianum							U						
Oocystis natans	U							U			U		
Pediastrum biradiatum								U			U		
Pediastrum boryanum					C		U	U	U		U	U	
Pediastrum duplex	C	C			C		C	C	C		C	U	U
Pediastrum simplex		U			U		U						
Scenedesmus abundans											U		
Scenedesmus acuminatus		U					C	U	U		U	U	
Scenedesmus armatus					U						U		
Scenedesmus bijuga											U		
Scenedesmus dimorphus					U			U					
Scenedesmus quadricauda		C			C		C	U	C		U	U	
Selenastrum westii					U		U	U	C		U	U	
Sphaerocystis schroeteri			U										
Westella botryoides	C	U						U					

(Continued on following page)

Table 6. (Continued). Net plankton collected in 1958 at a station in the Ohio River between the Louisville Municipal Boat Harbor and Twelve Mile Island, except November 5* and 19*, which are both from near the mouth of Silver Creek, Indiana. Relative abundance indicated by: A--abundant, C--common, and U--uncommon.

	October				November						December		
ALGAL SPECIES	10	17	24	31	4	5*	13	17	19	19*	4	5	17
OTHER GREEN ALGAE													
Spirogyra sp.				U	U								U
Mougeotia sp.													U
Stigeoclonium sp.						U							
BLUE-GREEN ALGAE													
Anacystis aeruginosa	U	U	U	C							U		U
Oscillatoria sp.						C	U		C			U	U
Anabaena sp.				U									
OTHER ALGAE													
Synura uvella					C		U				C	U	
Mallomonas sp.	U												
Dinobryon sertularia											U		
Trachelomonas spp.					C						U		
Tribonema													U

Table 7. Tastes and odors of Ohio River water at Louisville, Kentucky, for the period of October through December 1958, as reported by the Louisville Water Company.

TASTE AND ODOR (Reported as identical on the same day)	October Days Reported	October Average Threshold Number T - O	November Days Reported	November Average Threshold Number T - O	December Days Reported	December Average Threshold Number T - O
Algae	1	4.0 - 5.6	3	3.7 - 5.2		
Algae, Fishy	6	5.0 - 7.2	15	5.6 - 7.9		
Algae, Fishy, Grassy	1	4.0 - 5.6	1	5.6 - 8.0		
Algae, Fishy, Rivery			1	5.6 - 8.0	1	8.0 - 11.0
Algae, Fishy, Solvent			1	5.6 - 8.0		
Algae, Grassy	4	4.4 - 5.9	5	5.2 - 7.5	1	5.6 - 8.0
Algae, Grassy, Fishy	2	4.8 - 6.8			1	
Algae, Muddy					1	4.0 - 5.6
Algae, Musty	1	4.0 - 5.6	1	1.0	5	4.0 - 5.6
Algae, Rivery	3	4.0 - 5.6				
Algae, Rivery, Fishy	1	4.0 - 5.6	1	5.6 - 8.0		
Algae, Solvent					1	4.0 - 5.6
Fishy, Algae	1	5.6 - 8.0				
Fishy, Rivery, Algae	1	4.0 - 5.6				
Fishy, Solvent	1	4.0 - 5.6				
Grassy, Algae, Fishy	1	5.6 - 8.0				
Grassy, Solvent, Algae					1	4.0 - 5.6
Musty			4	1.0	2	2.0 - 2.8
Musty, Fishy	1	2.8 -4.0				
Musty, Oily					2	2.0 - 2.8
Musty, Rivery	1	2.0 - 2.8			1	2.8 - 4.0
Musty, Solvent	2	2.4 - 2.4			3	2.0 - 2.8
Oily					1	2.0 - 2.8
Oily, Fishy					1	2.0 - 2.8
Oily, Musty					5	2.0 - 2.8
Oily, Musty, Rivery					1	2.0 - 2.8
Oily, Rivery					3	2.0 - 2.8
Rivery					1	2.0 - 2.8
Rivery, Algae	1	2.8 - 4.0				
Rivery, Musty	1	2.0 - 2.8				
Rivery, Solvent	1	2.8 - 4.0				
Solvent	1	2.0 - 2.8				
Solvent, Algae					1	2.8 - 2.0

Table 8. An interpretation of the tastes and odors of Ohio River water at Louisville, Kentucky, for the period of October through December 1958, as reported by the Louisville Water Company.

TASTE AND ODOR (Reported as identical on the same day)	October No. Days Reported	October	November No. Days Reported	November	December No. Days Reported	December
Algae	1		3			
Algae, Fishy	6		15			
Algae, Fishy, Grassy	1	Abundant diatoms, with green algae, blue-green algae, plus other factors	1			
Algae, Fishy, Rivery			1		1	
Algae, Fishy, Solvent			1	Abundant diatoms, and green algae		
Algae, Grassy	4		5		1	
Algae, Grassy, Fishy	2					Algae scarce, diatoms, and green algae
Algae, Muddy					1	
Algae, Musty	1		1		5	
Algae, Rivery	3					
Algae, Rivery, Fishy	1		1			
Algae, Solvent					1	
Fishy, Algae	1	Animal origin in part				
Fishy, Rivery, Algae	1					
Fishy, Solvent	1					
Grassy, Solvent, Algae	1				1	
Musty			4		2	
Musty, Fishy	1					
Musty, Oily		Actino-mycetes?		Actino-mycetes?	2	Actino-mycetes?
Musty, Rivery	1				1	
Musty, Solvent	2				3	
Oily					1	
Oily, Fishy		Chemical and others			1	Chemical and others
Oily, Musty					5	
Oily, Musty, Rivery					1	
Oily, Rivery					3	
Rivery		Plant and animal origin, some chemical			1	
Rivery, Algae	1					
Rivery, Musty	1					
Rivery, Solvent	1					
Solvent	1	Chemicals mostly				
Solvent, Algae					1	

Table 9. Monthly bacterial population counts of the sediments from three sites in the Ohio River at Mile 599.1.

Date	Kentucky Side	Mid River	Indiana Side
	TOTAL BACTERIA COUNT		
10/2/59	1,600,000	1,900,000	1,200,000
11/2/59	4,600,000	8,200,000	3,700,000
12/2/59	1,291,000	3,900,000	1,600,000
1/2/60	2,900,000	10,600,000	4,400,000
	COLIFORM PLATE COUNT		
10/2/59	180,000	120,000	130,000
11/2/59	56,000	284,000	4,000
12/2/59	55,000	153,000	138,000
1/2/60	45,000	398,000	72,000

Table 10. Major tributaries of the Ohio River, their confluence and their drainage areas.

RIVER	MILES BELOW PITTSBURGH	DRAINAGE AREA Square Miles
Beaver	25.4	3,145
Muskingum	172.2	8,040
Little Kanawha	184.6	2,320
Hocking	199.4	1,185
Kanawha	265.7	12,300
Guyandot	305.3	1,670
Big Sandy	317.1	4,280
Scioto	356.5	6,510
Little Miami	464.1	1,755
Licking	470.2	3,670
Miami	491.1	3,950
Kentucky	545.7	6,940
Salt	629.9	2,890
Green	784.2	9,220
Wabash	848.0	33,100
Cumberland	920.4	18,000
Tennessee	940.0	40,600

Table 11. Number of collections taken by each of the different methods, during each of the three years of the study, and for the three years combined.

	1957	1958	1959	Total
Rotenone:				
Main stream lock chambers	29	55	40	124
Tributaries to main stream	16	29	33	78
Lock chambers in tributaries	6	4	2	12
Tributaries to tributaries	3	--	--	3
Backwaters in main stream	3	--	5	8
Hoopnets	2	--	37	39
Seines	5	13	8	26
Electric shocker	--	--	20	20
Otter trawl	6	4	8	18
Gill nets	--	1	8	9
Trammel nets	--	--	2	2
Pole and line	--	--	2	2
TOTAL	70	105	166	341

Table 12. Fishes of which more than 1,000 individuals or at least 100 pounds were taken during the three-year study period, arranged in order of decreasing numerical abundance, together with the total weight contributed by each, and its rank in the collections.

Species	Number	Weight (lbs.)	Rank Number	Rank Weight
Emerald shiner (Notropis atherinoides)	428,463	1,222.63	1	5
Gizzard shad (Dorosoma cepedianum)	107,165	14,583.68	2	1
Freshwater drum (Aplodinotus grunniens)	50,607	2,949.48	3	4
Mimic shiner (Notropis volucellus)	50,241	103.72	4	20
Channel catfish (Ictalurus punctatus)	22,722	3,556.86	5	3
Silver chub (Hybopsis storeriana)	11,789	162.21	6	14
Black bullhead (Ictalurus melas)	8,878	563.49	7	9
Threadfin shad (Dorosoma petenense)	8,003	132.36	8	15
Blue catfish (Ictalurus furcatus)	6,473	586.90	9	8
Sand shiner (Notropis stramineus)	3,633	9.66	10	23
Skipjack herring (Alosa chrysochloris)	3,550	1,136.63	11	6
Bluegill (Lepomis macrochirus)	3,532	102.99	12	21
Carp (Cyprinus carpio)	2,886	3,574.78	13	2
Longear sunfish (Lepomis megalotis)	2,545	87.52	14	22
Bluntnose minnow (Pimephales notatus)	2,023	6.85	15	25
Flathead catfish (Pylodictis olivaris)	1,619	856.86	16	7
River shiner (Notropis blennius)	1,416	5.11	17	27
Silvery minnow (Hybognathus nuchalis)	1,381	8.33	18	24
White crappie (Pomoxis annularis)	1,243	116.98	19	18
River carpsucker (Carpiodes carpio)	1,157	469.80	20	10
Troutperch (Percopsis omiscomaycus)	1,083	5.47	21	26
Golden redhorse (Moxostoma erythrurum)	744	169.09	22	13
Spotted sucker (Minytrema melanops)	609	259.21	23	12
Smallmouth buffalo (Ictiobus bubalus)	504	329.39	24	11
Largemouth bass (Micropterus salmoides)	258	126.20	25	16
Quillback (Carpiodes cyprinus)	171	125.34	26	17
Paddlefish (Polyodon spathula)	38	109.82	27	19

Table 13. Number of fish taken, and the total poundage, for each of the three years of the study period.

	Number	Weight	Collections
1957	137,223	9,728.00	70
1958	417,232	14,952.11	105
1959	186,983	7,998.70	166
Total	741,438	32,678.81	341

Table 14. Numbers and weights of fishes of which more than 500 individuals or more than 100 pounds were taken in one or more years of the three-year study period, 1957-1959.

Species	1957		1958		1959	
	Number	Weight	Number	Weight	Number	Weight
Skipjack herring	515	71.15	857	363.68	2,178	701.80
Gizzard shad	33,706	6,169.08	42,755	7,343.04	30,704	1,091.56
Threadfin shad	6,848	115.62	3	0.07	1,152	17.03
River carpsucker	204	89.21	492	259.24	461	121.35
Quillback	7	4.35	22	8.92	142	112.07
Smallmouth buffalo	190	140.29	137	188.74	177	117.36
Spotted sucker	15	10.18	191	87.10	403	161.93
Stoneroller	27	0.35	3	0.01	547	3.51
Carp	742	505.09	1,135	1,718.25	1,009	1,351.92
Silvery minnow	770	6.31	595	1.84	16	0.18
Silver chub	2,388	28.08	4,970	92.21	4,431	41.92
Emerald shiner	49,773	227.60	295,228	857.96	83,462	137.07
River shiner	664	2.60	281	1.13	471	1.38
Ghost shiner	---	----	880	1.38	9	0.03
Sand shiner	85	0.26	2,098	5.40	1,450	4.00
Mimic shiner	11,545	18.13	33,817	70.40	4,879	15.19
Bluntnose minnow	802	1.99	639	2.47	582	2.39
Blue catfish	533	122.34	1,731	161.07	4,209	303.49
Black bullhead	1,039	108.11	3,531	270.07	4,308	185.31
Channel catfish	2,645	682.72	9,583	1,557.76	10,494	1,316.38
Flathead catfish	499	284.79	409	304.92	711	267.15
Troutperch	997	4.92	60	0.40	26	0.09
Bluegill	1,184	31.79	1,871	52.34	477	18.86
Longear sunfish	726	43.62	708	19.98	1,101	23.92
White crappie	306	34.20	383	37.18	554	45.60
Freshwater drum	15,885	688.78	6,309	993.46	28,413	1,267.24

Table 15. Designations and locations of locks and dams in the Ohio River and sizes of lock chambers sampled.

U.S. Government Lock and Dam	Ohio River Mile	Location (n.=near)	Size of Chamber Sampled
Emsworth	6.2	below Pittsburgh	56 x 360
Dashields	13.3	below Pittsburgh	56 x 360
Montgomery	31.7	below Pittsburgh	56 x 360
Lock No. 8	46.4	n. Chester, Pa.	110 x 600
Lock No. 9	56.1	n. New Cumberland, W. Va.	110 x 600
Lock No. 10	66.2	n. Steubenville, Ohio	110 x 600
Lock No. 11	76.9	n. Brilliant, Ohio	110 x 600
Lock No. 12	87.4	Warwood, W. Va.	110 x 600
Lock No. 14	114.0	n. Clarington, Ohio	110 x 600
Lock No. 15	129.1	n. Duffy, Ohio	110 x 600
Lock No. 16	146.5	n. New Metamoras, Ohio	110 x 600
Lock No. 17	167.5	n. Reno, Ohio	110 x 600
Lock No. 18	179.9	n. Constitution, Ohio	110 x 600
Lock No. 19	192.2	n. Parkersburg, W. Va.	110 x 600
Lock No. 20	202.5	n. Belleville, W. Va.	110 x 600
Lock No. 21	214.6	n. Portland, Ohio	110 x 600
Lock No. 22	220.9	n. Ravenswood, W. Va.	110 x 600
Lock No. 23	231.4	Apple Grove, Ohio	110 x 600
Gallipolis	279.2	Gallipolis, Ohio	56 x 360
Lock No. 27	301.0	n. Athalia, Ohio	110 x 600
Lock No. 28	311.6	Sybene, Ohio	110 x 600
Lock No. 29	319.9	Ashland, Ky.	110 x 600
Lock No. 30	339.4	n. Greenup, Ky.	110 x 600
Lock No. 31	359.3	South Portsmouth, Ky.	110 x 600
Lock No. 32	382.6	Vanceberg, Ky.	110 x 600
Lock No. 33	405.1	n. Maysville, Ky.	110 x 600
Lock No. 34	434.1	Chilo, Ohio	110 x 600
Lock No. 35	451.0	California, Ky.	110 x 600
			110 x 1200
Lock No. 36	460.4	Silver Grove, Ky.	110 x 600
Lock No. 37	483.2	n. Sayler Park, Ohio	110 x 600
Lock No. 38	503.5	n. Belleview, Ky.	110 x 600
Lock No. 39	531.7	Markland, Ind.	110 x 600
			110 x 1200
McAlpine	607.0	Louisville, Ky.	56 x 360
Lock No. 43	633.2	n. New Boston, Ind.	110 x 600
Lock No. 44	663.1	Leavenworth, Ind.	110 x 600
Lock No. 45	703.0	n. Addison, Ky.	110 x 600
Lock No. 46	757.3	Owensboro, Ky.	110 x 600
Lock No. 47	777.7	Newburgh, Ind.	110 x 600
Lock No. 48	809.6	n. Evansville, Ind.	110 x 600
Lock No. 49	845.0	n. Uniontown, Ky.	110 x 600
Lock No. 50	876.8	n. Marion, Ky.	110 x 600
Lock No. 51	903.1	n. Golconda, Ill.	110 x 600
Lock No. 52	938.9	Brookport, Ill.	110 x 600
Lock No. 53	962.6	n. Grand Chain, Ill.	110 x 600

Table 16. Numbers and weights of each species of fish, of which 50 or more individuals were taken, listed in order of decreasing, total, numerical abundance, taken during each of the three years of the study period and for the three years combined, from McAlpine Lock, auxiliary chamber, Louisville, Kentucky.

	1957		1958		1959		Total	
Species	Number	Weight	Number	Weight	Number	Weight	Number	Weight
Emerald shiner	15,388	81.17	11,348	69.29	14,058	33.12	40,794	183.58
Gizzard shad	2,323	365.44	9,157	1,239.70	10,375	626.71	21,855	2,231.85
Freshwater drum	1,775	80.07	2,106	116.31	2,584	109.42	6,465	305.80
Skipjack herring	237	18.64	83	24.71	1,302	659.44	1,622	702.70
Silver chub	150	1.85	640	9.22	515	6.39	1,305	17.46
Channel catfish	406	63.82	412	75.33	151	19.73	969	158.88
Mimic shiner	711	1.78	8	0.03	32	0.08	751	1.89
Carp	129	62.64	68	58.70	142	63.64	339	184.98
River shiner	97	0.35	5	0.02	10	0.02	112	0.39
Green sunfish	82	1.29	5	0.02	5	0.16	92	1.47
Blue catfish	20	1.54	49	3.01	1	0.08	70	4.63
Flathead catfish	31	1.14	20	15.86	16	2.10	67	19.10
Smallmouth buffalo	2	0.23	8	5.43	48	1.71	58	7.37
Bluegill	37	0.73	7	0.04	10	0.14	54	0.91
Orange-spotted sunfish	14	0.17	0	0.00	38	0.48	52	0.65
Goldeye	21	8.84	8	1.68	21	9.37	50	19.89
All others	112	22.86	70	11.63	56	5.63	238	40.12
Total	21,535	712.56	23,994	1,631.16	29,364	1,538.22	74,893	3,881.94

Table 17. Numbers and weights, in pounds, of fishes taken by each method of sampling, for each year of the three-year study period.

Method	1957		1958		1959	
	Number	Weight	Number	Weight	Number	Weight
Rotenone						
Mainstream lock chambers	80,399	6,574.56	281,413	12,499.49	133,859	4,622.74
Mouths of tributary streams	6,605	466.52	129,833	1,735.21	10,896	1,794.35
Mainstream backwaters	19,217	2,107.83	-----	-----	5,476	211.42
Lock chambers in tributary streams	20,524	465.24	3,671	674.73	10,262	188.33
All rotenone samples	126,745	9,614.15	414,917	14,909.43	160,493	6,816.84
Hoopnets	32	30.78	-----	-----	678	675.06
Seines	7,081	31.04	2,301	39.60	22,642	51.07
Electric shocker	-----	-----	-----	-----	361	324.61
Otter trawl	3,365	52.03	84	3.08	2,211	25.83
Miscellaneous	-----	-----	-----	-----	528	105.29
All samples other than rotenone	10,478	113.85	2,385	42.68	26,420	1,181.86
TOTAL	137,223	9,728.00	417,302	14,952.11	186,913	7,998.70

Table 18. Percentages of total fishes, by numbers and by weights, taken during the three-year study period by the different sampling methods used.

Method	Percentage Number	Percentage Weight	Number of Collections
Rotenone			
Mainstream lock chambers	66.85	72.51	124
Mouths of tributary streams	19.74	12.02	78
Mainstream backwaters	3.33	7.10	8
Locks in tributary streams	4.65	4.06	12
Tributaries to tributary streams	0.13	0.21	3
All rotenone	94.70	95.90	225
Hoopnets	0.10	2.16	39
Seines	4.32	0.37	26
Electric shocker	0.05	1.00	20
Otter trawl	0.76	0.25	18
Miscellaneous	0.07	0.32	13
All other than rotenone	5.30	4.10	116
TOTAL	100.00	100.00	341

Table 19. Numbers and weights, in pounds, of fishes taken by each method of sampling, for each hundred-mile section of the Ohio River during the three-year study period.

Section of River	0-100 Miles		100-200 Miles		200-300 Miles		300-400 Miles	
Method	Number	Weight	Number	Weight	Number	Weight	Number	Weight
Rotenone								
Mainstream lock chambers	11,391	392.78	191,603	1,702.66	66,841	749.72	19,530	1,959.14
Mouths of tributary streams	88,145	629.39	5,042	98.45	33,505	414.06	3,773	1,059.69
Mainstream backwaters	4,469	293.80	---	---	---	---	1,094	9.80
Lock chambers in tributary streams	18,755	145.44	---	---	191	30.75	---	---
All rotenone samples	122,760	1,461.41	196,645	1,801.11	100,537	1,194.53	24,397	3,028.63
Hoopnets	159	80.71	88	87.59	---	---	68	53.96
Seines	455	1.42	---	---	---	---	28	0.44
Electric shocker	45	45.87	---	---	---	---	104	131.12
Otter trawl	---	---	---	---	---	---	---	---
Miscellaneous	289	29.97	---	---	---	---	---	---
All samples other than rotenone	948	157.97	88	87.59	---	---	200	185.52
Total	123,708	1,619.38	196,733	1,888.70	100,537	1,194.53	24,597	3,214.15

(Continued)

Table 19. Numbers and weights, in pounds, of fishes taken by each method of sampling, for each hundred-mile section of the Ohio River during the three-year study period (Continued).

Section of River	400-500 Miles		500-600 Miles		600-700 Miles		700-800 Miles	
Method	Number	Weight	Number	Weight	Number	Weight	Number	Weight
Rotenone								
Mainstream lock chambers	12,505	1,665.99	6,651	743.83	91,061	5,069.53	63,985	8,008.78
Mouths of tributary streams	2,725	202.72	5,939	476.62	2,481	174.17	779	44.34
Mainstream backwaters	---	---	647	36.58	13,143	1,344.08	---	---
Lock chambers in tributary streams	9,232	122.30	749	141.03	---	---	4,332	659.78
All rotenone samples	24,462	1,991.01	13,986	1,398.06	106,685	6,587.78	69,096	8,712.90
Hoopnets	221	183.13	---	---	118	263.56	---	---
Seines	74	0.40	292	1.61	29,128	59.68	789	15.96
Electric shocker	63	72.00	---	---	149	75.62	---	---
Otter trawl	---	---	4,733	67.16	843	10.70	---	---
Miscellaneous	12	9.60	---	---	190	33.52	---	---
All samples other than rotenone	370	265.13	5,025	68.77	30,428	443.08	789	15.96
Total	24,832	2,256.14	19,011	1,466.83	137,113	7,030.86	69,885	8,728.86

(Continued)

Table 19. Numbers and weights, in pounds, of fishes taken by each method of sampling, for each hundred-mile section of the Ohio River during the three-year study period (Concluded).

Section of River	800-900 Miles		900-981 Miles		Total	
Method	Number	Weight	Number	Weight	Number	Weight
Rotenone						
Mainstream lock chambers	14,586	1,726.75	17,518	1,677.61	495,671	23,696.79
Mouths of tributary streams	2,655	459.55	2,290	437.09	147,334	3,996.08
Mainstream backwaters	3,029	608.23	2,311	26.76	24,693	2,319.25
Lock chambers in tributary streams	---	---	1,198	229.00	34,457	1,328.30
All rotenone samples	20,270	2,794.53	23,317	2,370.46	702,155	31,340.42
Hoopnets	---	---	56	36.89	710	705.84
Seines	327	17.35	931	24.85	32,024	121.71
Electric shocker	---	---	---	---	361	324.61
Otter trawl	84	3.08	---	---	5,660	80.94
Miscellaneous	---	---	37	32.20	528	105.29
All samples other than rotenone	411	20.43	1,024	93.94	39,283	1,338.39
Total	20,681	2,814.96	24,341	2,464.40	741,438	32,678.81

Table 20. Numbers and weights, in pounds, of fishes taken from the lock chambers in each of the hundred-mile sections of the Ohio River, together with the standing crops for each section based on the weighted averages of the studies for each section.

Section	Number of Collections	Number of Fish	Weight of Fish	Standing Crop
1	11	11,391	392.78	38
2	9	191,603	1,702.66	124
3	6	66,841	749.72	92
4	15	19,530	1,959.14	81
5	13	12,505	1,665.99	84
6	7	6,651	743.83	70
7	34	91,061	5,069.53	230
8	11	63,985	8,008.78	479
9	9	14,586	1,726.75	126
10	9	17,518	1,677.61	122
Total or Average	124	495,671	23,696.79	155

Table 21. Numbers and weights, in pounds, of fishes taken from the mouths of streams tributary to the Ohio River in each hundred-mile section, together with the numbers of collections taken in each section and the numbers of pounds of fish taken per collection.

Section	Number of Collections	Number of Fish	Weight of Fish	Weight of Fish per Collection
0	3	979	69.34	23.11
1	4	87,166	560.05	140.01
2	3	5,042	98.45	32.82
3	10	33,505	414.06	41.41
4	8	3,773	1,059.74	132.47
5	13	2,722	202.71	15.59
6	7	5,941	473.21	67.60
7	14	2,488	174.85	12.49
8	2	779	44.34	22.17
9	10	2,648	459.42	45.94
10	7	2,302	437.38	62.48
TOTAL	81	147,345	3,993.55	49.30

Table 22. Localities on the Ohio River where intensive studies were made with gear other than rotenone during 1959, together with the dates for each locality.

Locality	Dates of Collections
Section 1, approximately 30 miles downstream from Pittsburgh, Pa.	June 26-29 July 24-27
Section 2, approximately 20 miles downstream from Wheeling, W. Va.	June 29-July 1 July 27-29
Section 4, at Ashland, Ky.	June 17-19 July 14-17 August 14-18
Section 5, approximately 10 miles downstream from Cincinnati, Ohio	June 12-17 July 10-12
Section 7, approximately 20 miles downstream from Louisville, Ky.	June 5-10 July 7-9 August 10-12
Section 10, near Mound City, Ill.	August 25-28

Table 23. Percentage frequency of occurrence of those species of fishes taken in at least 20 per cent of the collections made by each of four methods, Ohio River, 1957-1959.

Hoopnets		Seines		Electric Shocker		Otter Trawl	
Percentage Frequency	Species	Percentage Frequency	Species	Percentage Frequency	Species	Percentage Frequency	Species
51.3	Carp	100.0	Emerald shiner	75.0	Carp	94.4	Silver chub
46.2	Channel catfish	80.8	River shiner	55.0	Gizzard shad	88.9	Channel catfish
43.6	Flathead catfish	65.4	Gizzard shad	45.0	Channel catfish	61.1	Freshwater drum
41.0	White crappie	53.8	River carpsucker	40.0	Emerald shiner	38.9	Mimic shiner
33.3	Freshwater drum	50.0	Silver chub	35.0	River carpsucker	33.3	Gizzard shad
33.3	Black crappie	30.8	Silvery minnow	30.0	Smallmouth buffalo	27.8	Emerald shiner
30.8	Black bullhead	30.8	Mimic shiner	----	------------	22.2	Speckled chub
23.1	Bluegill	26.9	Skipjack herring	----	------------	----	------------
20.5	Spotted bass	26.9	Sand shiner	----	------------	----	------------
----	------------	23.1	Channel catfish	----	------------	----	------------
----	------------	23.1	Smallmouth buffalo	----	------------	----	------------
----	------------	23.1	Longnose gar	----	------------	----	------------

Table 24. Creel census statistics resulting from a three-year creel census on the Kentucky portion of the Ohio River (1957-1959).

	1957			1958			1959		
	Upper	Middle Sections	Lower	Upper	Middle Sections	Lower	Upper	Middle Sections	Lower
Completed creel cards returned	221	189	334	247	241	355	466	709	1,611
Number of fishermen censused	378	393	603	403	455	625	690	1,060	2,614
Average size of fishing party	1.7	2.1	1.9	1.6	1.9	1.8	1.5	1.5	1.6
Successful fishermen (per cent)	79.9	76.6	87.9	74.7	62.0	90.2	66.1	66.3	69.6
Male fishermen (per cent)	86.2	80.9	85.7	86.8	83.7	81.9	91.0	88.7	85.6
Female fishermen (per cent)	13.8	19.1	14.3	13.2	16.3	18.1	9.0	11.3	14.4
Resident fishermen (per cent)	98.4	77.4	59.8	96.0	76.7	64.0	87.4	89.2	73.6
Non-resident fishermen (per cent)	1.6	22.6	40.2	4.0	23.3	36.0	12.6	10.8	26.4
Number of hours fished	646.5	1,349.5	2,270.5	791.0	1,155.5	2,083.5	1,419.3	2,843.0	5,839.5
Average time fished when censused	1.71	3.43	3.60	1.96	2.54	3.33	2.06	2.68	2.23
Total trips annually to Ohio River (anglers' estimate)	8,467	7,064	11,974	6,025	5,379	9,896	20,745	26,914	59,429
Average trips per year per angler	22.4	18.0	19.0	15.0	11.8	15.8	30.1	25.4	22.7

(Continued on following page)

Table 24 (Continued). Creel census statistics resulting from a three-year creel census on the Kentucky portion of the Ohio River (1957-1959).

	1957 Upper	1957 Middle	1957 Lower	1958 Upper	1958 Middle	1958 Lower	1959 Upper	1959 Middle	1959 Lower
	Sections			Sections			Sections		
Total cost (anglers' estimate)	667.35	1,383.80	1,262.25	700.00	904.80	1,352.50	1,294.60	2,727.45	7,854.75
Average cost per trip per angler	1.77	3.52	2.00	1.74	1.99	2.16	1.88	2.57	3.00
Average cost per year per angler	39.65	63.36	38.00	26.10	23.48	34.13	56.59	65.28	68.10
Fishing method used (per cent)									
Still fishing	80.9	79.1	92.7	75.2	90.1	87.0	89.1	93.8	94.0
Casting	4.5	14.5	4.9	13.2	3.3	6.9	6.4	3.5	3.6
Trolling	1.6	2.0	0.3	---	2.4	1.12	---	1.0	0.4
Trotlines	12.9	4.3	2.1	11.7	4.2	4.0	4.2	1.3	1.5
Gigging	---	---	---	---	---	0.96	---	0.4	---
Other	---	---	---	---	---	---	0.3	---	0.5
Fish per hour	1.03	0.63	1.10	1.09	0.60	1.37	0.79	0.47	1.37
Average time (hrs.) to catch one fish	0.97	1.59	0.91	0.92	1.67	0.73	1.27	2.13	0.73
Fish caught per trip	1.76	2.16	3.96	2.14	1.52	4.56	1.63	1.26	3.06
Total number of fish caught	668	851	2,499	863	696	2,844	1,122	1,344	7,972
Total length of fish caught (inches)	8,383	9,631	29,938	9,950	9,152	34,884	13,277	16,406	97,699
Average length (inches) of all fish caught	12.5	11.3	12.0	11.5	13.1	12.3	11.8	12.2	12.3

Table 25. Composition of the catches of 7 commercial fishermen in the Ohio River between Mile 317 and Mile 535 (218 miles) during 1958.

Species	Number of Fish Caught	Per cent of Total Number	Weight in Pounds	Mean Weight (lbs.)	Per cent of Total Weight
COMMERCIAL					
Carp	854	11.2	6,983	8.2	32.0
Channel catfish	2,576	33.9	4,759	1.8	21.8
Flathead catfish	321	4.2	1,408	4.4	6.5
Freshwater drum	868	11.4	1,387	1.6	6.4
Blue catfish	744	9.8	1,365	1.8	6.3
Carpsuckers	321	4.2	1,166	3.6	5.3
Smallmouth buffalo	156	2.1	969	6.2	4.4
Bullheads	168	2.2	764	4.5	3.5
Suckers	363	4.8	640	1.8	2.9
Bigmouth buffalo	59	0.8	389	6.6	1.8
Paddlefish	3	Tr.	19	6.3	0.1
ALL COMMERCIAL	6,433	84.6	19,849	3.1	91.0
SPORT					
Walleye	77	1.0	231	3.0	1.1
Crappies	161	2.1	122	0.8	0.6
Sauger	18	0.2	36	2.0	0.2
White Bass	17	0.2	18	1.1	0.1
Black basses	8	0.1	12	1.5	0.1
ALL SPORT	281	3.6	419	1.5	2.1
PREDATORY					
Gars	135	1.8	287	2.1	1.3
ALL PREDATORY	135	1.8	287	2.1	1.3
FORAGE					
Skipjack Herring	707	9.3	1,185	1.7	5.4
Mooneye, Goldeye	45	0.6	54	1.2	0.2
ALL FORAGE	752	9.9	1,239	1.6	5.6
TOTAL ALL SPECIES	7,601	99.9	21,794	2.9	100.0

Table 26. Composition of the catches of 14 commercial fishermen in the Ohio River between Mile 535 and Mile 742 (207 miles) during 1958.

Species	Number of Fish Caught	Per cent of Total Number	Weight in Pounds	Mean Weight (lbs.)	Per Cent of Total Weight
COMMERCIAL					
Channel catfish	11,768	61.3	11,495	1.0	42.7
Carp	794	4.1	5,180	6.5	19.2
Freshwater drum	2,777	14.5	2,820	1.0	10.5
Flathead catfish	803	4.2	2,311	2.9	8.6
Carpsuckers	640	3.3	1,172	1.8	4.4
Blue catfish	793	4.1	944	1.2	3.5
Bigmouth buffalo	128	0.7	764	6.0	2.8
Bullheads	428	2.2	752	1.8	2.8
Smallmouth buffalo	168	0.9	652	3.9	2.4
Suckers	460	2.4	603	1.3	2.2
Paddlefish	5	Tr.	16	3.2	0.1
Sturgeon	1	Tr.	4	4.0	Tr.
ALL COMMERCIAL	18,765	97.7	26,713	1.4	99.2
SPORT					
Crappies	164	0.9	45	0.3	0.2
Black basses	25	0.1	16	0.6	0.1
Sauger	10	0.1	15	1.5	0.1
Sunfishes	131	0.7	13	0.1	0.1
Walleye	4	Tr.	7	1.8	Tr.
White basses	11	0.1	6	0.5	Tr.
Rock bass	3	Tr.	2	0.7	Tr.
ALL SPORT	348	1.9	104	0.3	0.5
PREDATORY					
Gars	7	Tr.	38	5.4	0.1
ALL PREDATORY	7	Tr.	38	5.4	0.1
FORAGE					
Skipjack herring	62	0.3	58	0.9	0.2
Gizzard shad	16	0.1	15	0.9	0.1
Mooneye, Goldeye	3	Tr.	2	0.7	Tr.
ALL FORAGE	81	0.4	75	0.9	0.3
TOTAL ALL SPECIES	19,201	100.0	26,930	1.4	100.1

Table 27. Composition of the catches of 11 commercial fishermen in the Ohio River between Mile 742 and Mile 981 (239 miles) during 1958.

Species	Number of Fish Caught	Per cent of Total Number	Weight in Pounds	Mean Weight (lbs.)	Per cent of Total Weight
COMMERCIAL					
Carp	4,606	11.3	16,115	3.5	22.2
Channel catfish	13,553	33.2	11,893	0.9	16.4
Freshwater drum	8,004	19.6	11,698	1.5	16.1
Carpsuckers	7,721	18.9	8,804	1.1	12.1
Smallmouth buffalo	1,562	3.8	8,481	5.4	11.7
Blue catfish	3,191	7.8	7,659	2.4	10.6
Flathead catfish	891	2.2	2,997	3.4	4.1
Bigmouth buffalo	412	1.0	2,221	5.4	3.1
Paddlefish	119	0.3	1,353	11.4	1.9
Sturgeon	82	0.2	290	3.5	0.4
Suckers	21	0.1	55	2.6	0.1
Bullheads	42	0.1	57	1.4	0.1
ALL COMMERCIAL	40,204	98.5	71,623	1.8	98.8
SPORT					
Black basses	80	0.2	143	1.8	0.2
Sauger	39	0.1	96	2.5	0.1
White bass	40	0.1	66	1.6	0.1
Crappies	27	0.1	33	1.2	0.1
ALL SPORT	186	0.5	338	1.8	0.5
PREDATORY					
Gars	73	0.2	271	3.7	0.4
Eel	1	Tr.	2	2.0	Tr.
ALL PREDATORY	74	0.2	273	3.7	0.4
FORAGE					
Gizzard shad	394	1.0	366	0.9	0.5
Skipjack herring	10	Tr.	9	0.9	Tr.
ALL FORAGE	404	1.0	375	0.9	0.5
TOTAL ALL SPECIES	40,868	100.2	72,609	1.8	100.2

Table 28. Composition of the catches of 9 commercial fishermen in the Ohio River between Mile 317 and Mile 535 (218 miles) during 1959.

Species	Number of Fish Caught	Per cent of Total Number	Weight in Pounds	Mean Weight (lbs.)	Per cent of Total Weight
COMMERCIAL					
Channel catfish	6,806	62.0	5,297	0.8	37.0
Carp	727	6.6	2,364	3.2	16.5
Blue catfish	878	8.0	1,730	2.0	12.1
Flathead catfish	534	4.9	1,431	2.7	10.0
Freshwater drum	846	7.7	1,057	1.2	7.4
Carpsuckers	320	2.9	757	2.4	5.3
Smallmouth buffalo	93	0.9	377	4.1	2.6
Bigmouth buffalo	38	0.4	278	7.3	1.9
Suckers	70	0.6	156	2.2	1.1
Bullheads	27	0.3	71	2.6	0.5
Paddlefish	9	0.1	35	3.9	0.2
Sturgeon	1	Tr.	12	12.0	0.1
ALL COMMERCIAL	10,349	94.4	13,563	1.3	94.7
SPORT					
Black basses	18	0.2	30	1.7	0.2
Walleye	13	0.1	29	2.2	0.2
Sauger	10	0.1	22	2.2	0.2
White bass	21	0.2	13	0.6	0.1
Crappies	13	0.1	8	0.6	0.1
ALL SPORT	75	0.7	102	1.4	0.8
PREDATORY					
Gars	52	0.5	155	3.0	1.1
Eel	1	Tr.	4	4.0	Tr.
ALL PREDATORY	53	0.5	159	3.0	1.1
FORAGE					
Skipjack herring	430	3.9	471	1.1	3.3
Gizzard shad	63	0.6	32	0.5	0.2
ALL FORAGE	493	4.5	503	1.0	3.5
TOTAL ALL SPECIES	10,970	100.1	14,327	1.3	100.1

Table 29. Composition of the catches of 7 commercial fishermen in the Ohio River between Mile 535 and Mile 742 (207 miles) during 1959.

Species	Number of Fish Caught	Per cent of Total Number	Weight in Pounds	Mean Weight (lbs.)	Per cent of Total Weight
COMMERCIAL					
Channel catfish	2,103	57.6	5,013	2.4	44.8
Smallmouth buffalo	188	5.2	1,386	7.4	12.4
Bigmouth buffalo	187	5.1	1,184	6.3	10.6
Carp	108	3.0	804	7.4	7.2
Freshwater drum	387	10.6	775	2.0	6.9
Carpsuckers	346	9.5	724	2.1	6.5
Flathead catfish	123	3.4	439	3.6	3.9
Blue catfish	62	1.7	351	5.7	3.1
Suckers	27	0.7	42	1.6	0.4
Bullheads	15	0.4	35	2.3	0.3
ALL COMMERCIAL	3,546	97.2	10,753	3.0	96.1
SPORT					
(None reported)					
PREDATORY					
Gars	53	1.5	345	6.5	3.1
ALL PREDATORY	53	1.5	345	6.5	3.1
FORAGE					
Gizzard shad	47	1.3	78	1.6	0.7
Skipjack herring	7	0.2	13	1.8	0.1
ALL FORAGE	54	1.5	91	1.7	0.8
TOTAL ALL SPECIES	3,653	100.2	11,189	3.1	100.0

Table 30. Composition of the catches of 9 commercial fishermen in the Ohio River between Mile 742 and Mile 981 (239 miles) during 1959.

Species	Number of Fish Caught	Per cent of Total Number	Weight in Pounds	Mean Weight (lbs.)	Per cent of Total Weight
COMMERCIAL					
Channel catfish	18,998	51.2	16,151	0.8	33.6
Carp	3,854	10.4	11,100	2.9	23.1
Carpsuckers	7,398	19.9	7,128	1.0	14.8
Smallmouth buffalo	769	2.1	3,433	4.5	7.1
Bigmouth buffalo	532	1.4	1,879	3.5	3.9
Blue catfish	726	2.0	1,873	2.6	3.9
Flathead catfish	627	1.7	1,790	2.8	3.7
Freshwater drum	1,596	4.3	1,768	1.1	3.7
Paddlefish	49	0.1	336	6.8	0.7
Bullheads	4	Tr.	17	4.2	Tr.
Suckers	4	Tr.	10	2.5	Tr.
Sturgeon	2	Tr.	4	2.0	Tr.
ALL COMMERCIAL	34,559	93.1	45,489	1.3	94.5
SPORT					
White bass	655	1.8	269	0.4	0.6
Black basses	121	0.3	99	0.8	0.2
Walleye	25	0.1	36	1.4	0.1
Crappies	53	0.1	19	0.4	Tr.
ALL SPORT	854	2.3	423	0.5	0.9
PREDATORY					
Gars	79	0.2	246	3.1	0.5
Eel	2	Tr.	4	2.0	Tr.
ALL PREDATORY	81	0.2	250	3.1	0.5
FORAGE					
Skipjack herring	1,615	4.4	1,894	1.2	3.9
Gizzard shad	23	0.1	28	1.2	0.1
ALL FORAGE	1,638	4.5	1,922	1.2	4.0
TOTAL ALL SPECIES	37,132	100.1	48,084	1.3	99.9

Table 31. ORSANCO-UNIVERSITY OF LOUISVILLE Aquatic Life Project
FISH TASTE QUESTIONNAIRE

Date:____________________ Code____________

1. How soon were the fish eaten? (Same day____) (Next day)____ (_____days later

2. Were the fish refrigerated ( ) or frozen ( ) before cooking?

3. Were the fish skinned? (Yes________) (No______).

4. Were the fish soaked in anything before they were cooked? (Yes__) (No___).
If yes, what were they soaked in?____________________. Why were they soaked?
____

5. How were the fish prepared for cooking? (Rolled in cornmeal__) (Sauced__)
(Floured__) (Breaded__) (Other______________________________________)

6. How were the fish cooked? (Pan fried__) (Deep fat fried__) (Baked__)
(Broiled__) (Other____)

7. Describe the smell during cooking. (Very appetizing__) (About normal__)
(Unpleasant__). If the last, when did you first notice the unpleasant smell?
____________________________. Describe the smell______________

8. Did the fish look good after cooking? (Yes__) (No__). If no, describe how
they looked____

9. How many people tasted the fish?_________________________________

10. How many rated the fish as very good? ____________________
How many rated the fish as fair or average?____________
How many rated the fish as poor? ____________________

11. If poor, explain ____

12. Other remarks____
____

13. About how often do you eat fish? (About one or two times a week__) (About one or two times a month__) (Not as often as once a month__). (Other__________)

14. What is your favorite kind of fish?_________________________________

PLEASE RETURN THE COMPLETED FORM IN THE ENCLOSED SELF-ADDRESSED ENVELOPE.

AQUATIC-LIFE RESOURCES

OF THE OHIO RIVER

APPENDIX IV

FIGURES

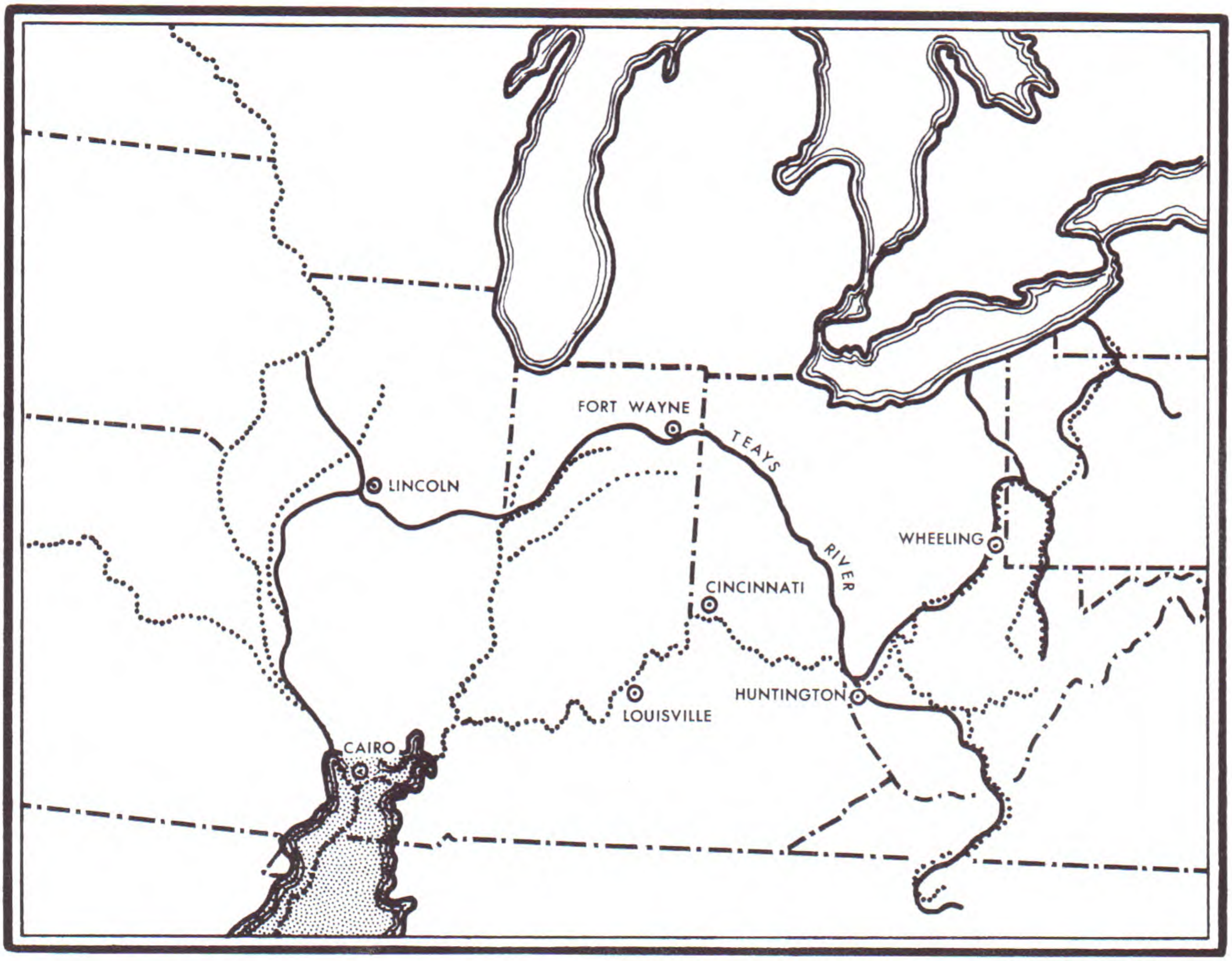
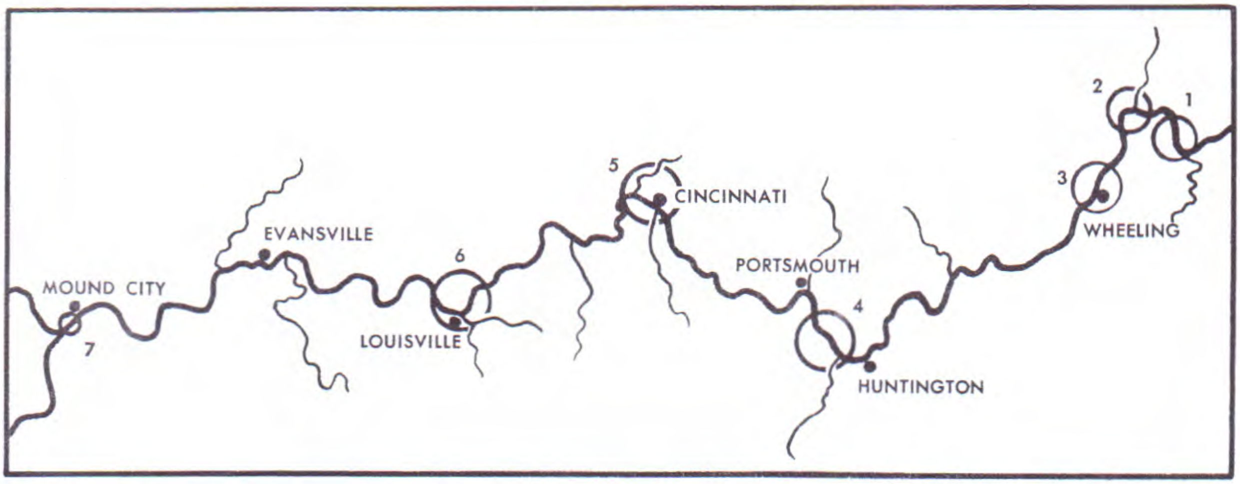


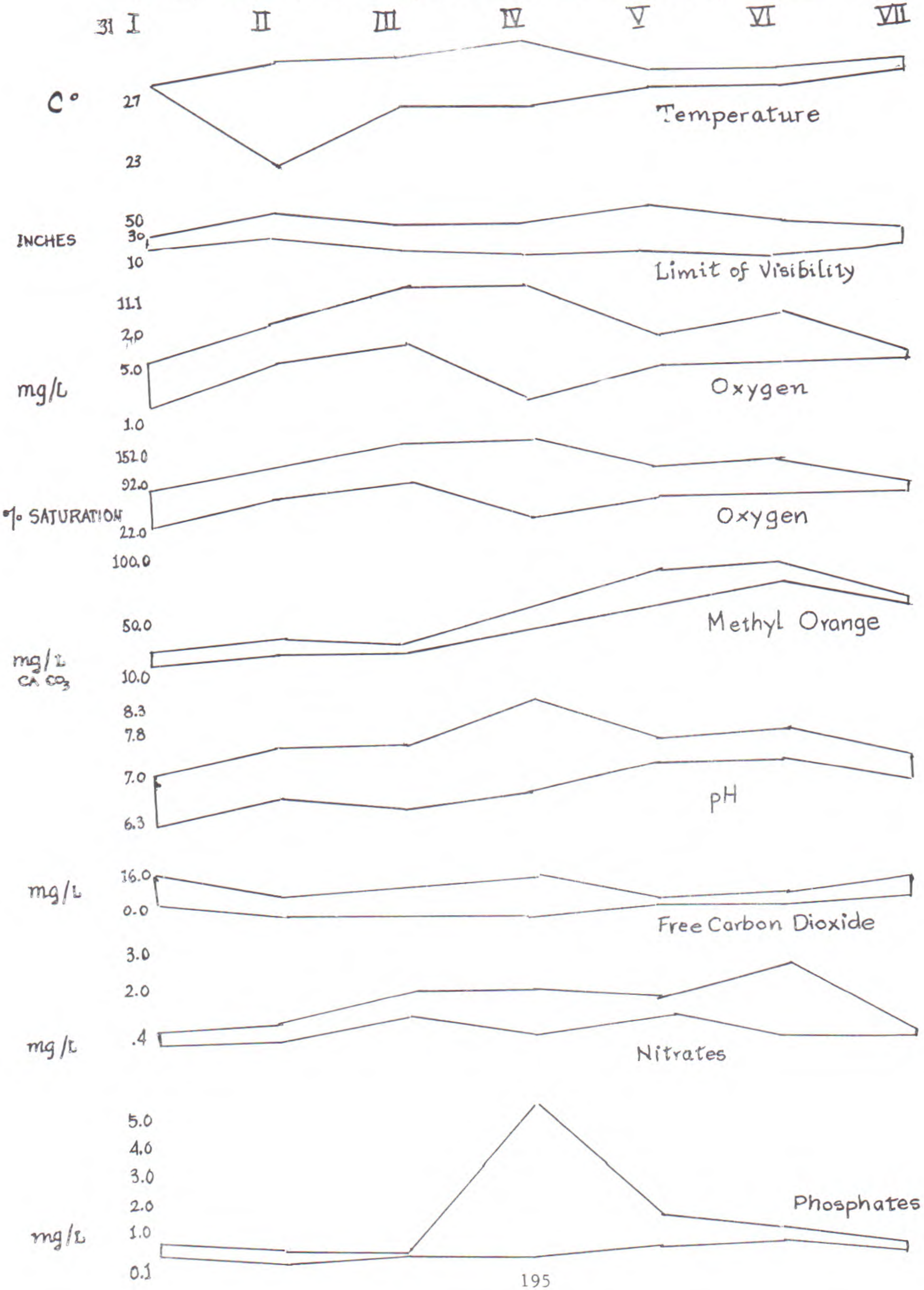
Figure 1. Teays River. Present rivers are shown in dotted lines; the extinct water-courses, in solid. The stippled body of water depicts the Gulf of Mexico. Where the dotted and solid lines run closely parallel, the present and ancient streams occupied the same course. (Modified from Janssen, 1952, and Walker, 1957)

Figure 2. Seven regions of the Ohio River selected for intensive limnological studies.



Region 1 - One mile above confluence of Allegheny and Monongahela Rivers to mile 10 in Ohio River.
Region 2 - Mile 15 in Ohio River to Montgomery Lock, mile 31.7.
Region 3 - Mile 88, Martin's Ferry, W. Va., to Lock 14, mile 114, below Wheeling, W. Va.
Region 4 - Mile 307.2, four miles above Lock 28, to mile 336.8, Greenup, Ky.
Region 5 - Mile 445 to below Cincinnati, Ohio at mile 484.
Region 6 - Mile 598, above Louisville, Ky., to mile 642.2, near Brandenburg, Ky.
Region 7 - Mile 973.6 near Mound City, Ill., eight miles above confluence of Ohio and Mississippi Rivers.

Figure 3. Comparative maximum-minimum values of selective chemical-physical factors measured in seven regions of the Ohio River during the summer of 1959.



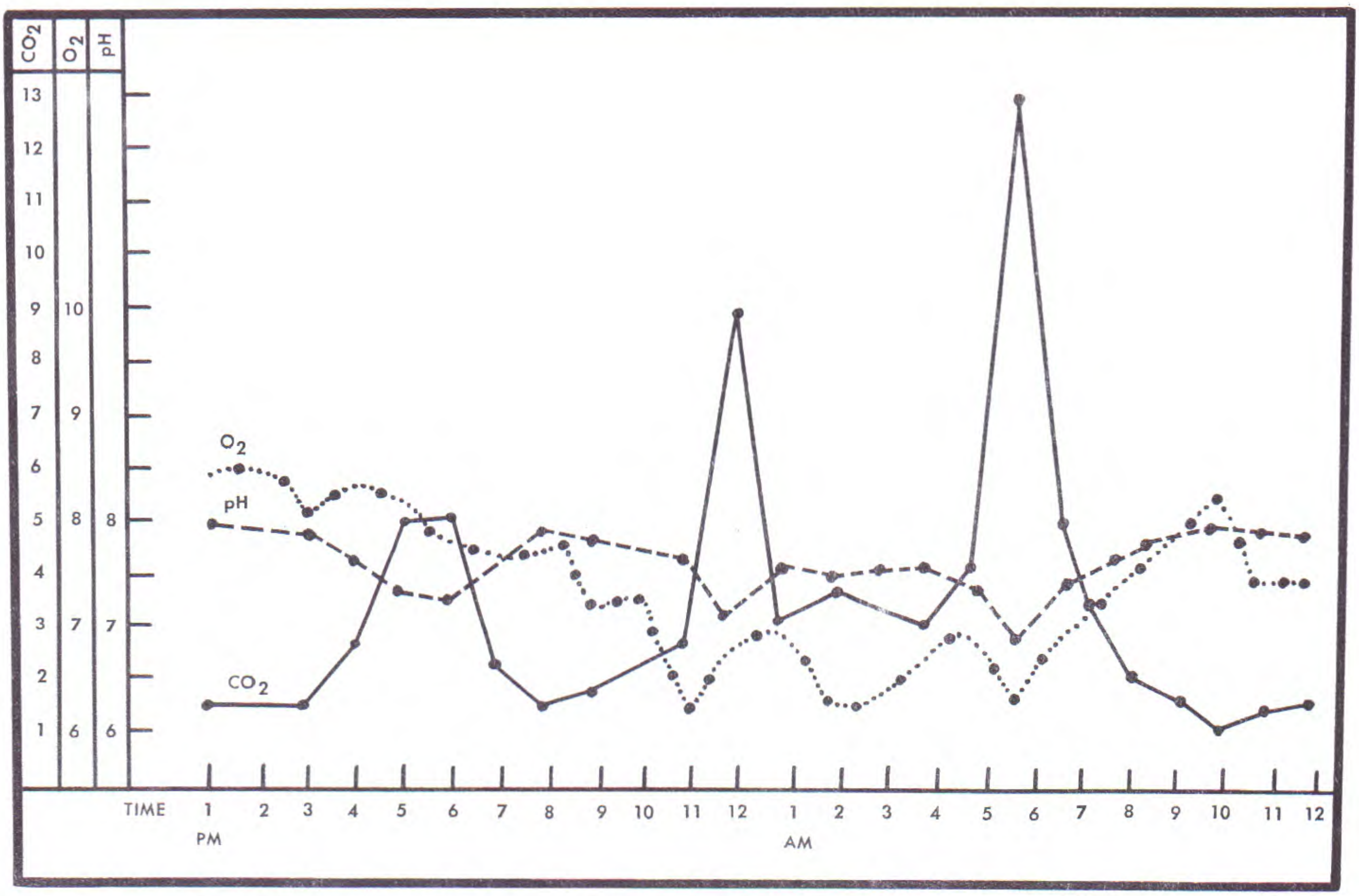


Figure 4. Dissolved oxygen, carbon dioxide, and pH values obtained at mile 322 during a 24-hour period, in ppm.

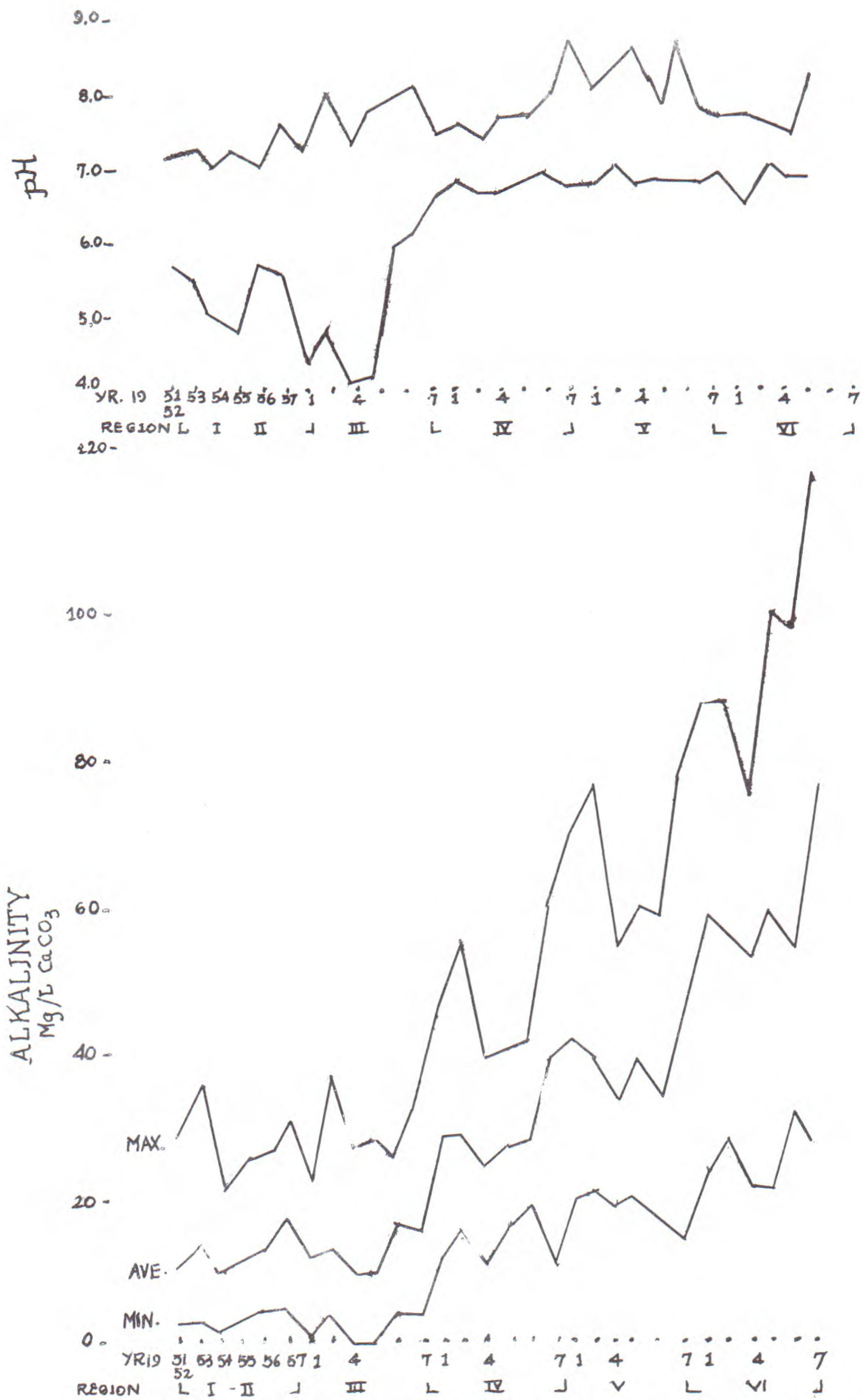


Figure 5. Composite graphs of the average annual total alkalinity and pH values in the Ohio River from Mile 0 to Mile 600 from 1951 through 1957. (The data from the years 1951-52 are combined.)

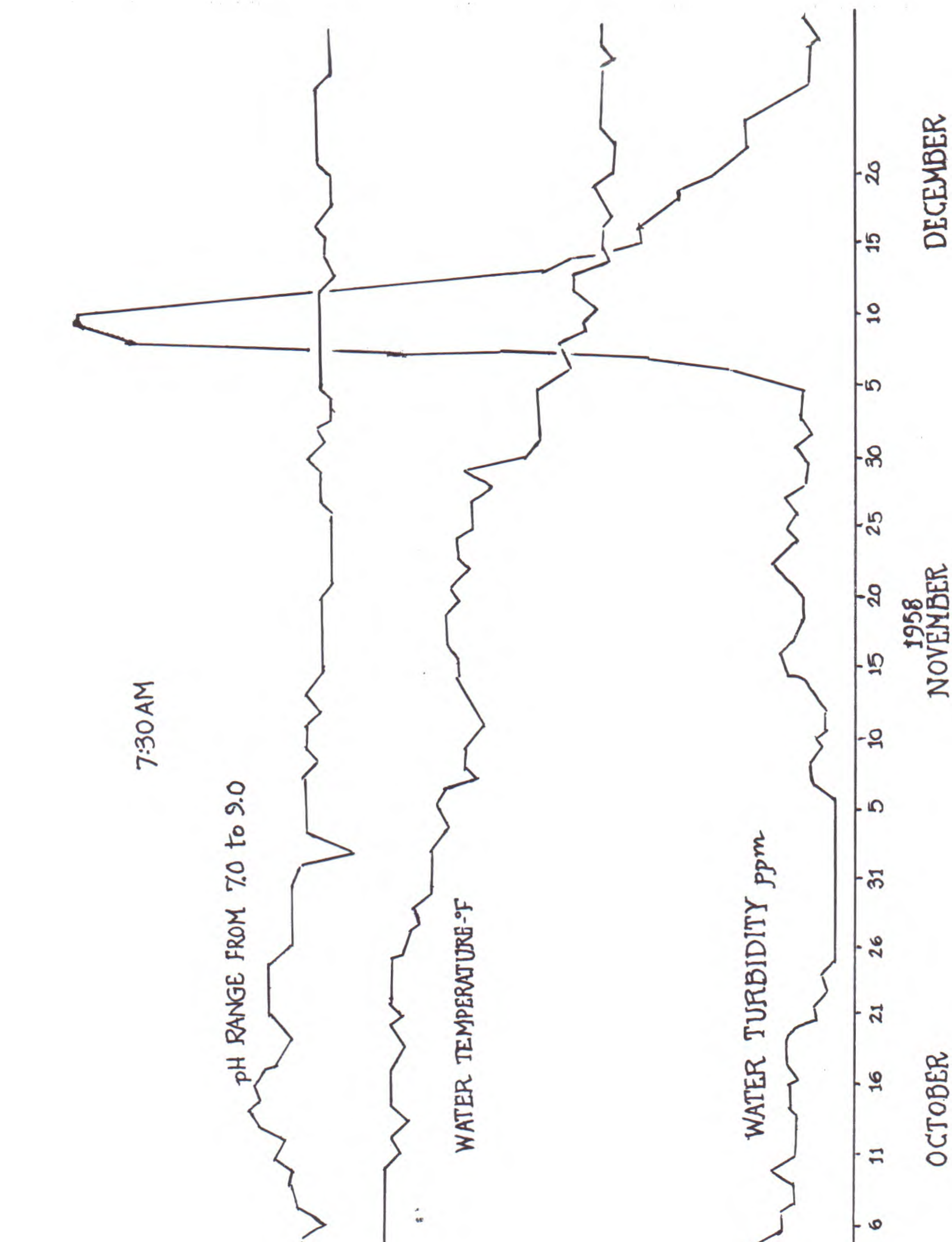


Figure 6. Turbidity, water temperature, and pH values obtained from the Louisville Water Company for the months of October, November, and December, 1958.

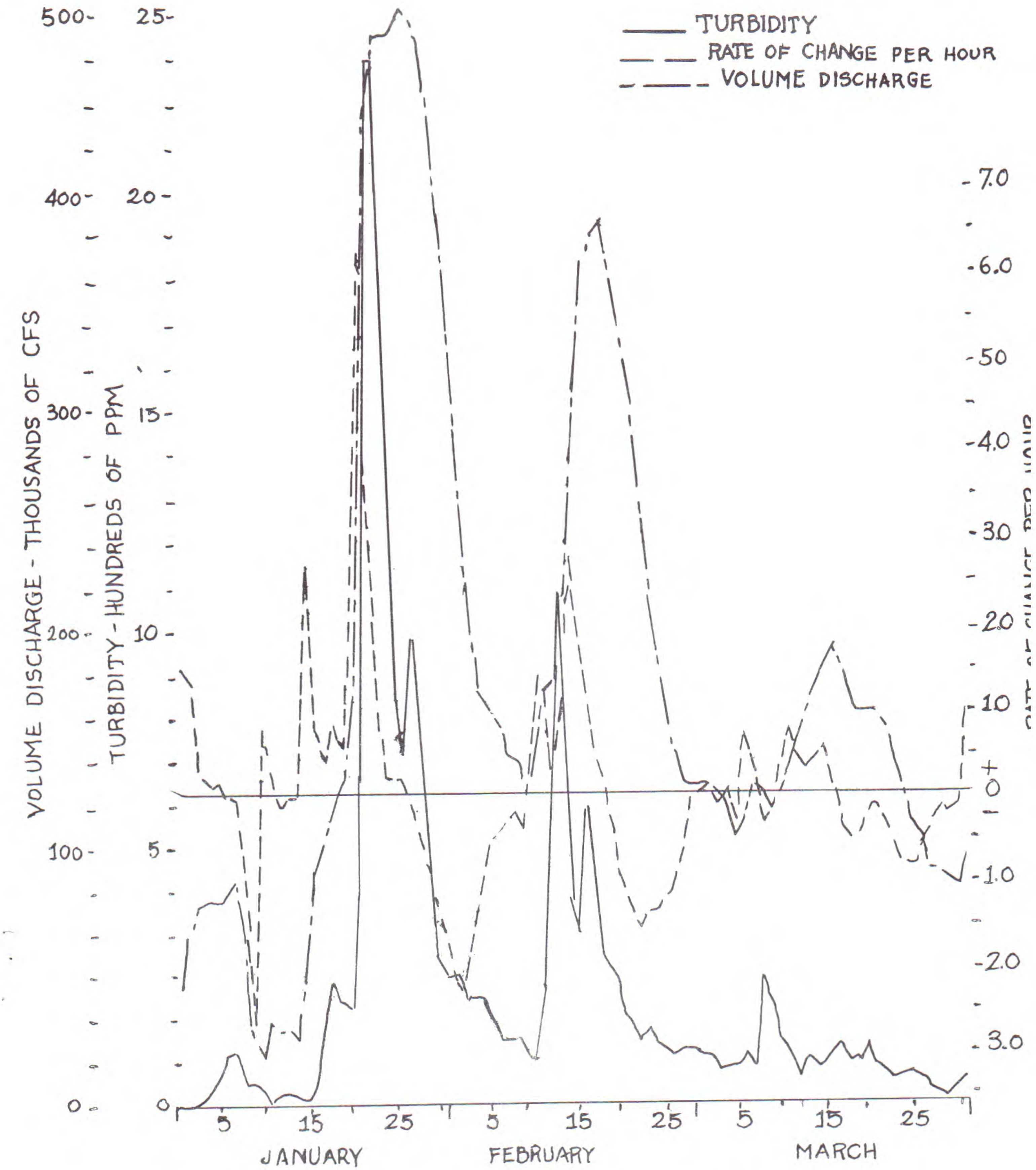


Figure 7. Volume of flow, rate of change per hour and turbidity of the Ohio River at Mile 607 during January, February and March of 1959.

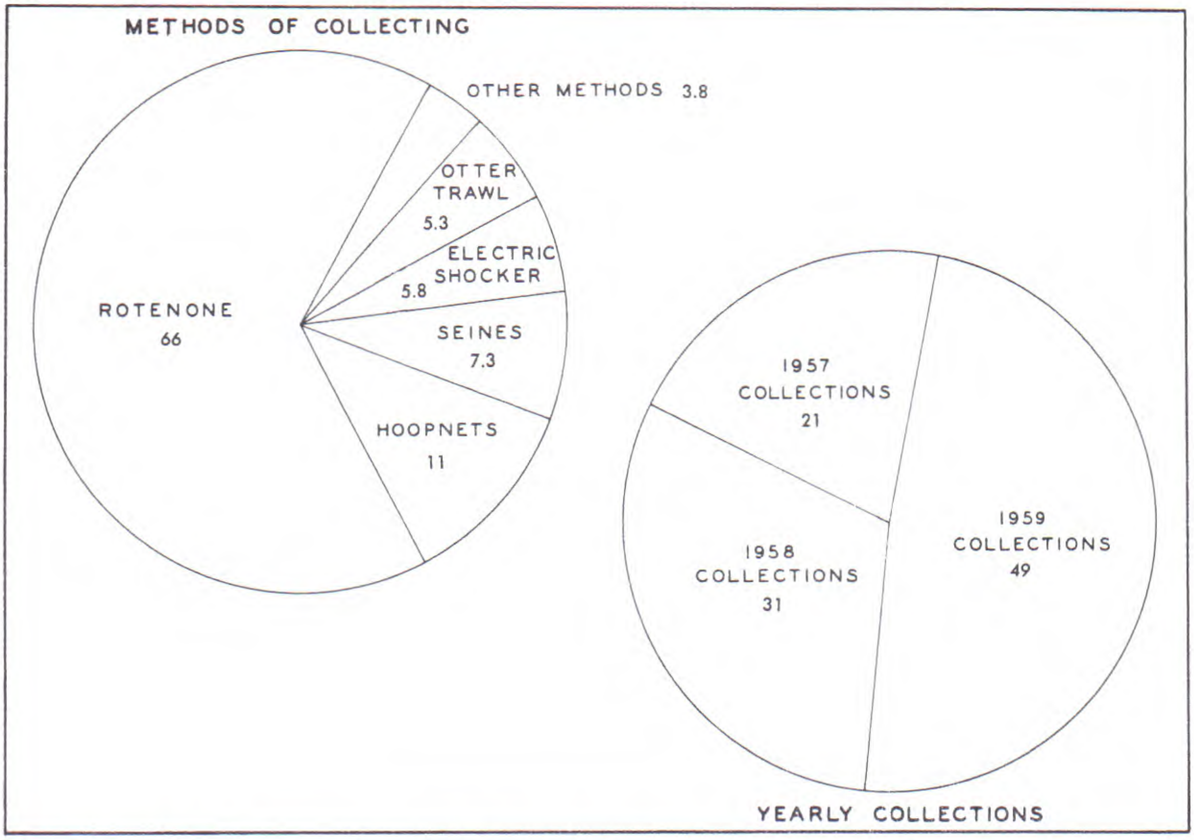


Figure 8. Percentages of all collections taken by five principal methods, and by other methods combined, during the three-year study period, together with the percentage of all collections taken during each year.

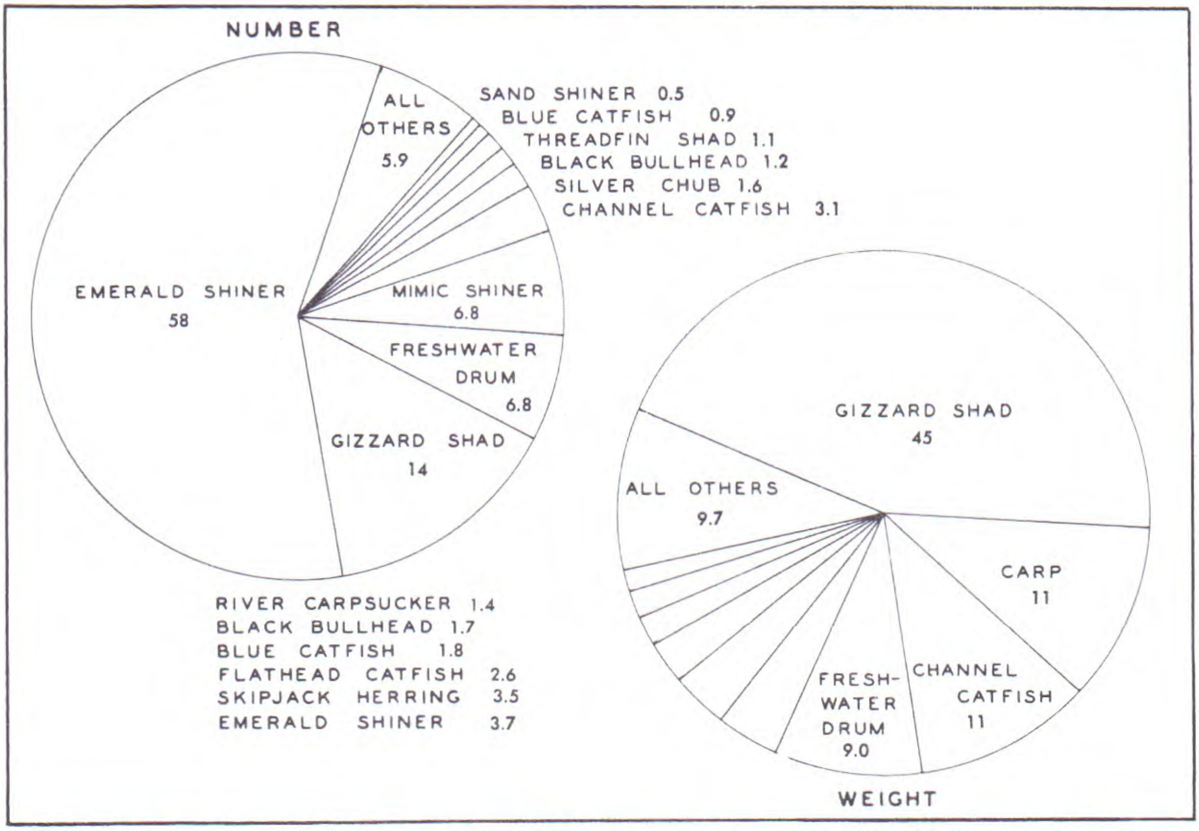


Figure 9. Percentages, by numbers and weights, of all fishes taken by all methods during the three-year study period. Only the 10 most abundant fishes in each category are listed separately; the others are combined.

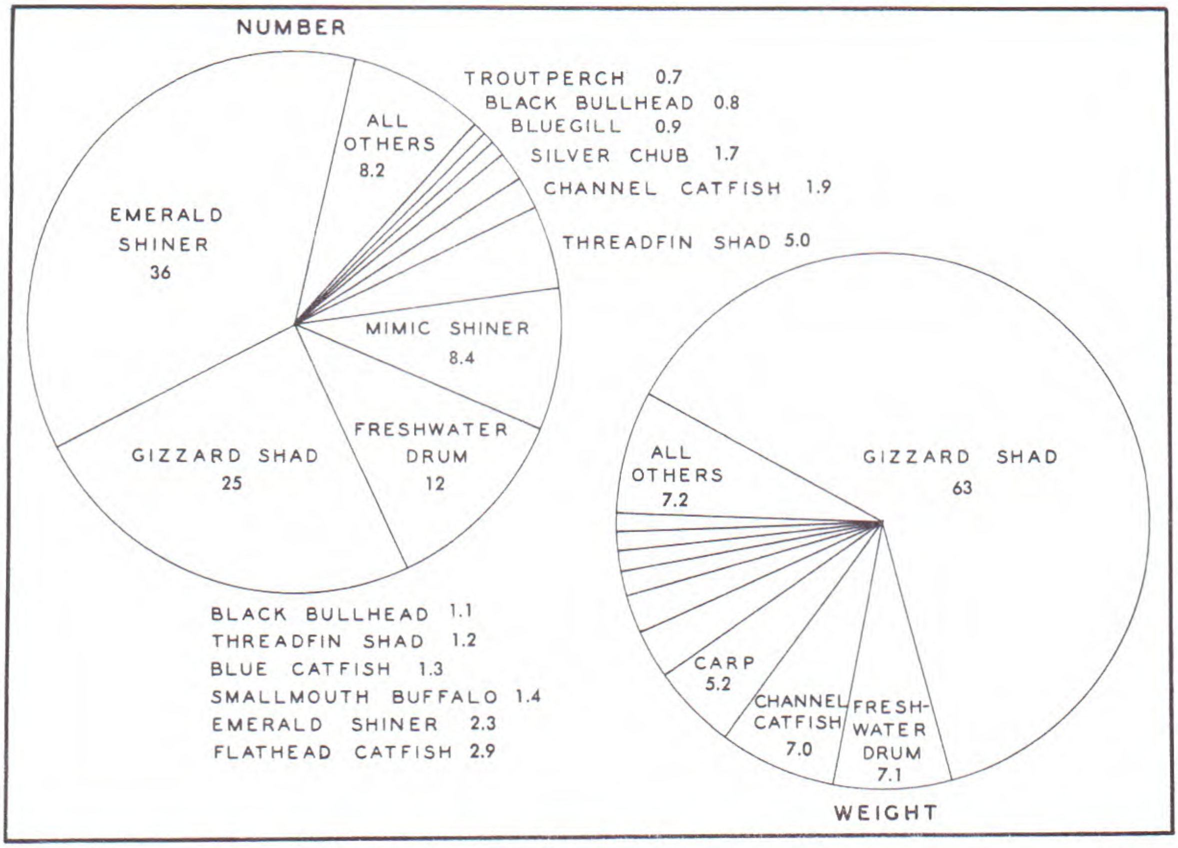


Figure 10 . Percentages, by numbers and weights, of all fishes taken by all methods during 1957. Only the 10 most abundant fishes in each category are listed separately; the others are combined.

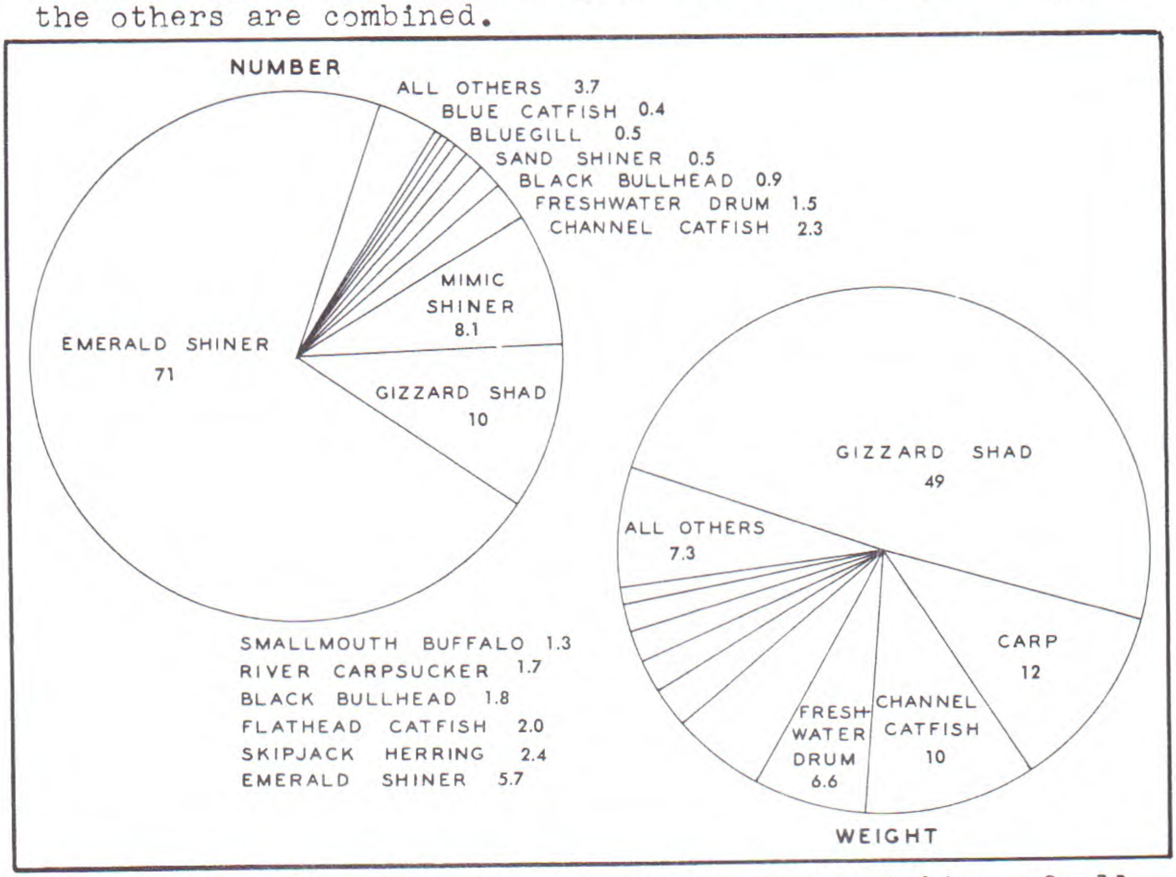


Figure 11 . Percentages, by numbers and weights, of all fishes taken by all methods during 1958. Only the 10 most abundant fishes in each category are listed separately; the others are combined.

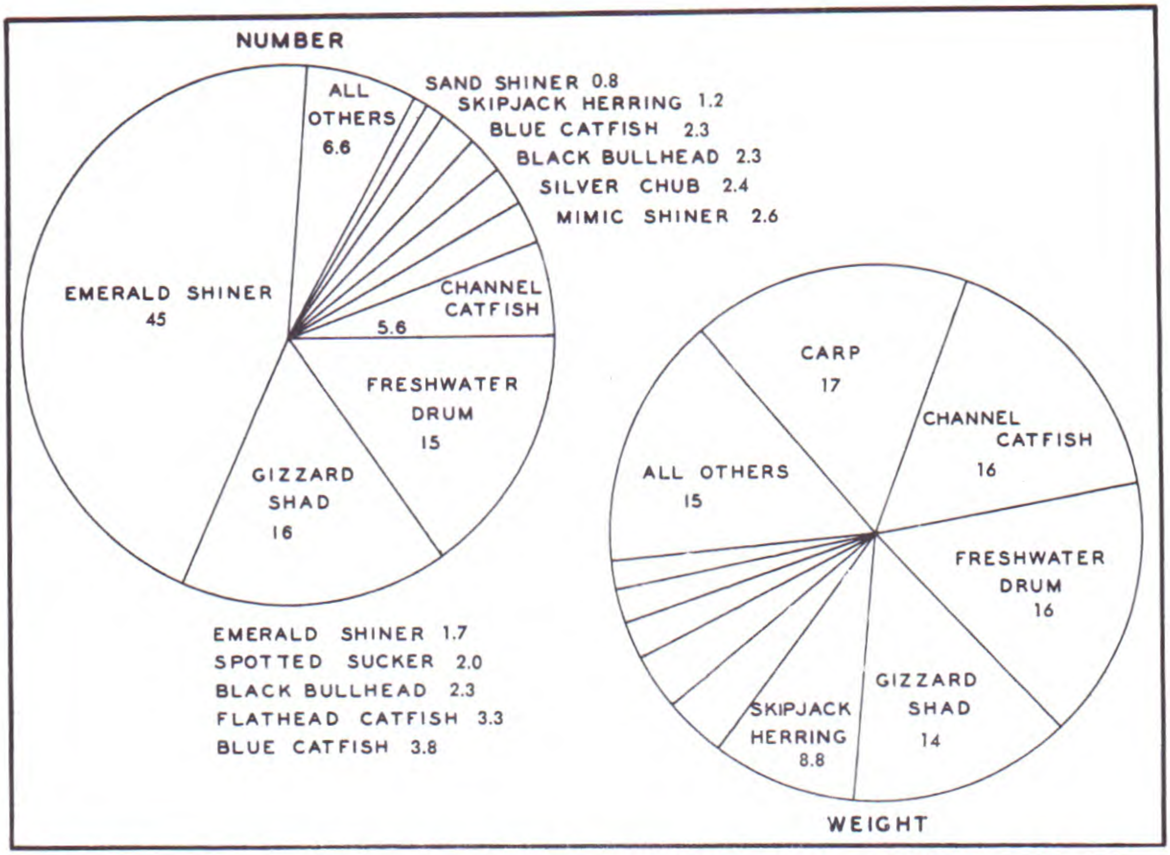


Figure 12 . Percentages, by numbers and weights, of all fishes taken by all methods during 1959. only the 10 most abundant fishes in each category are listed separately; the others are combined.

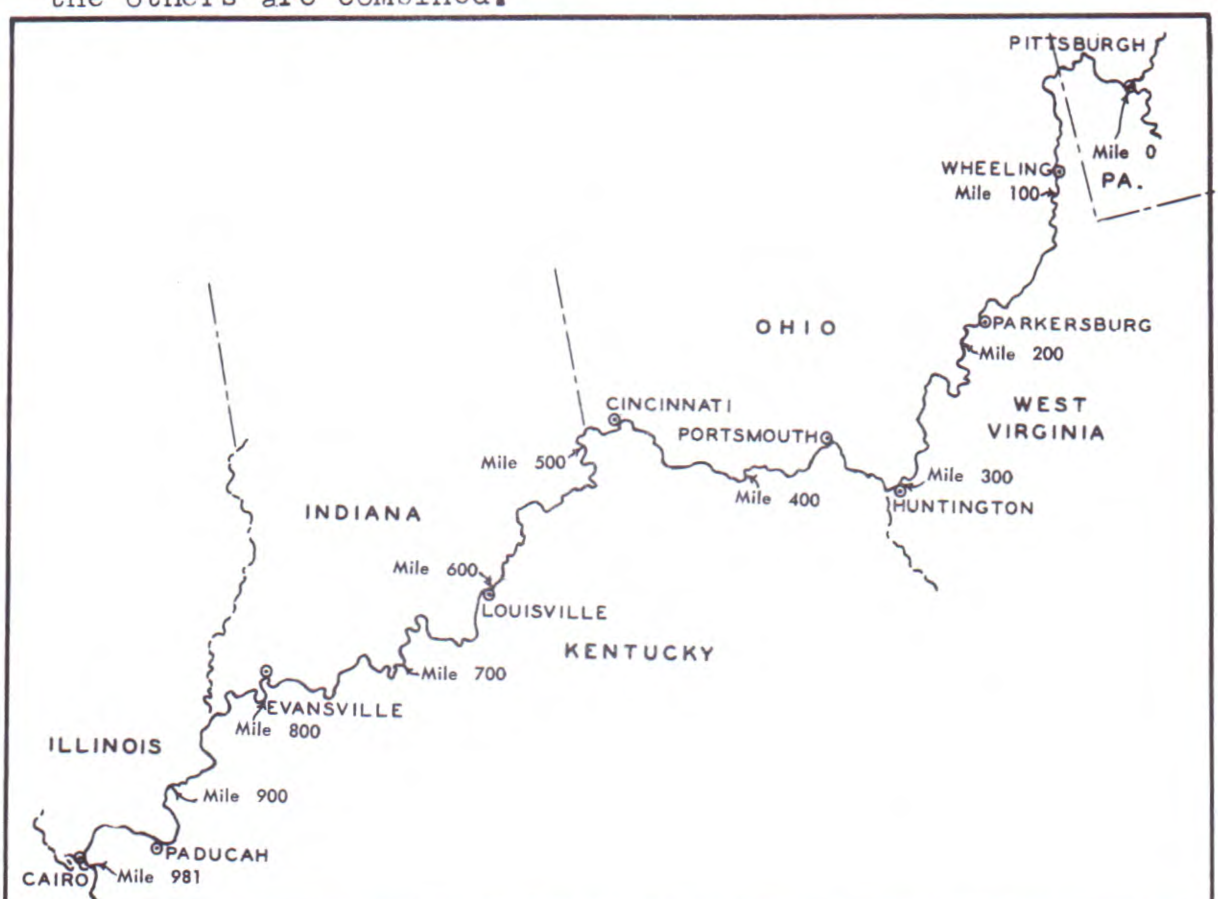


Figure 13 . Map of the Ohio River showing the mileages below Pittsburgh, the state boundaries, and the locations of some principal cities.

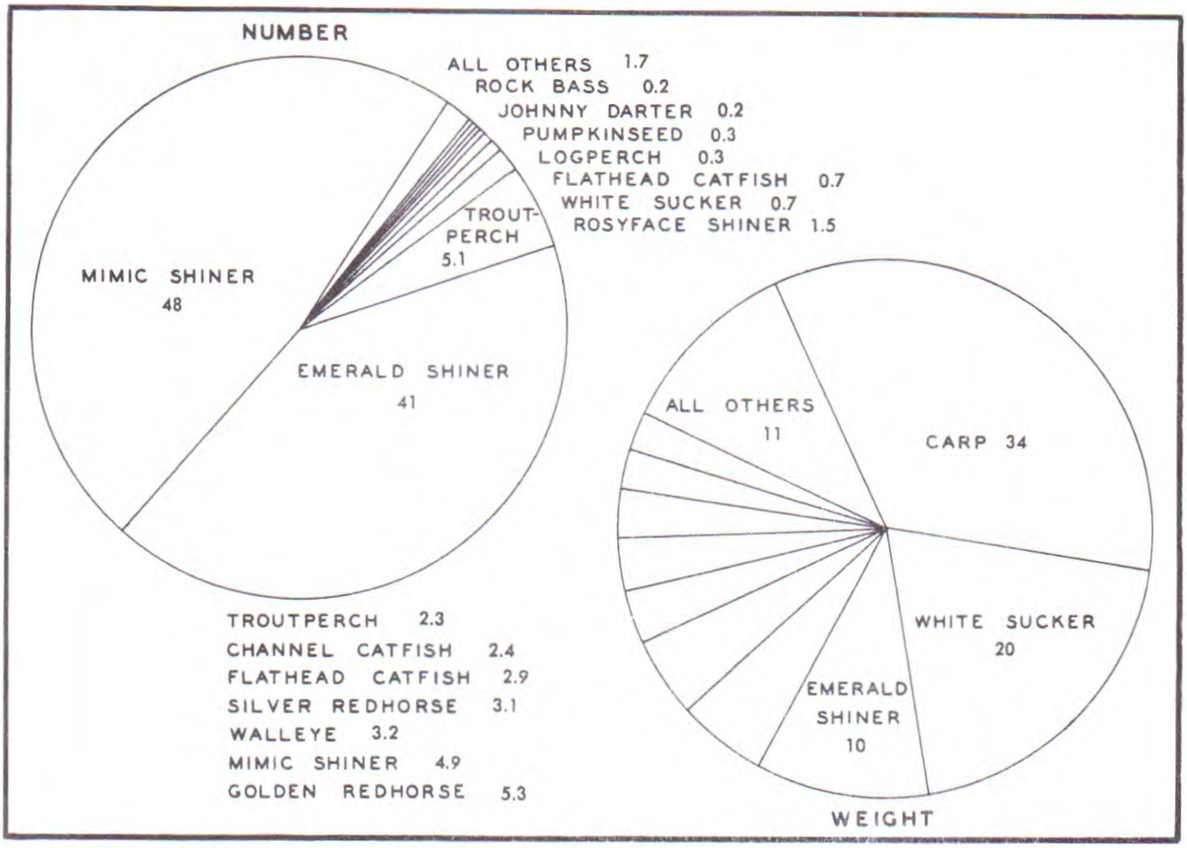


Figure 14 . Percentages, by numbers and weights, of all fishes taken by all methods from the Allegheny and Monongahela rivers and their tributaries (Section 0) during the three-year study period. Only the 10 most abundant fishes are listed separately; the others are combined.

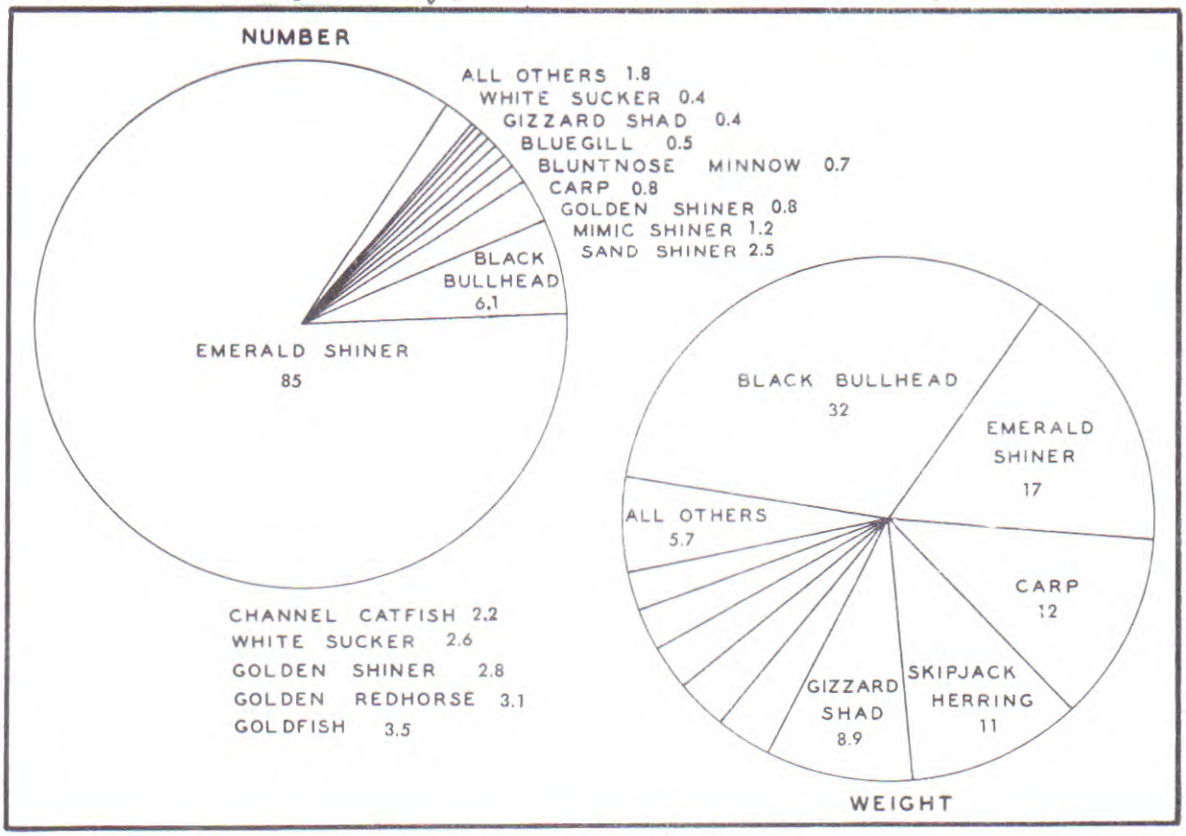


Figure 15 . Percentages, by numbers and weights, of all fishes taken by all methods between Pittsburgh and Ohio River Mile 100 (Section 1) during the three-year study period. Only the 10 most abundant fishes are listed separately; the others are combined.

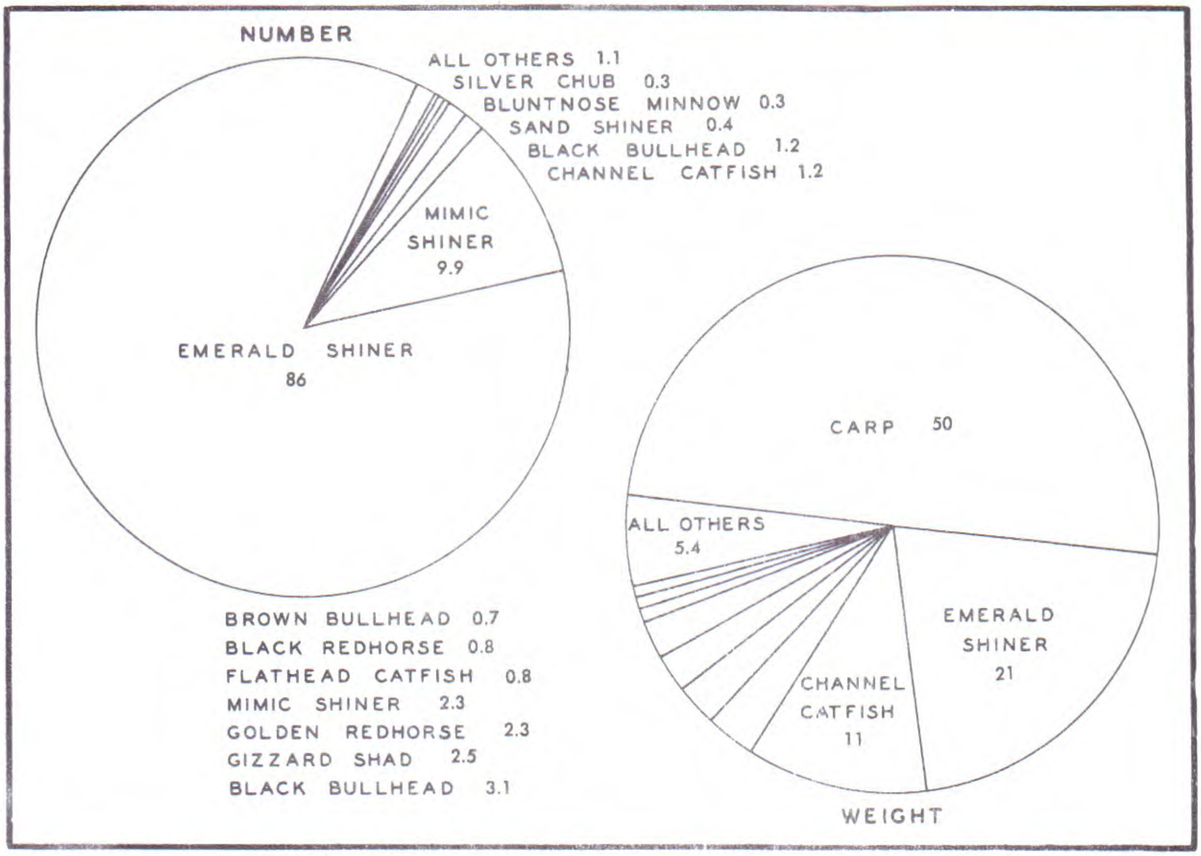


Figure 16. Percentages, by numbers and weights, of all fishes taken by all methods between Ohio River Miles 100 and 200 (Section 2) during the three-year study period. Only the 10 most abundant fishes are listed separately; the others are combined.

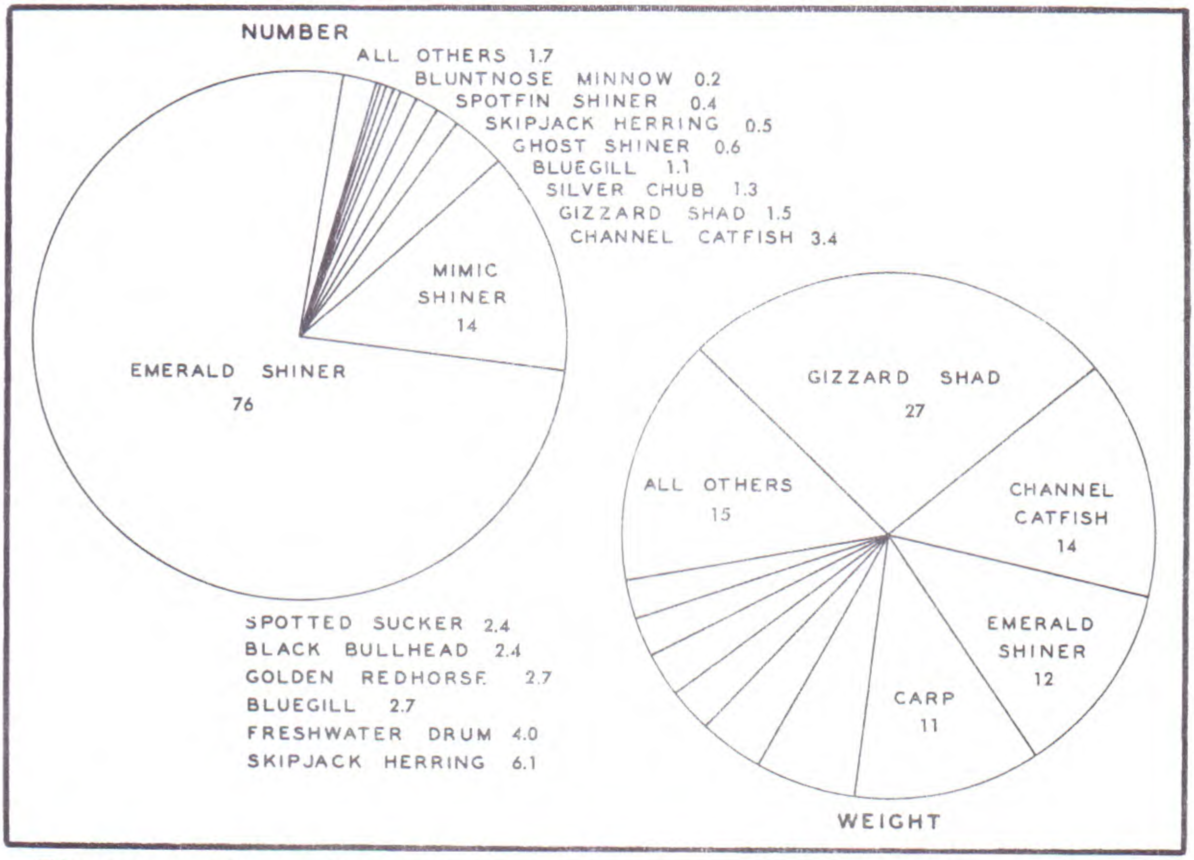


Figure 17. Percentages, by numbers and weights, of all fishes taken by all methods between Ohio River Miles 200 and 300 (Section 3) during the three-year study period. Only the 10 most abundant fishes are listed separately; the others are combined.

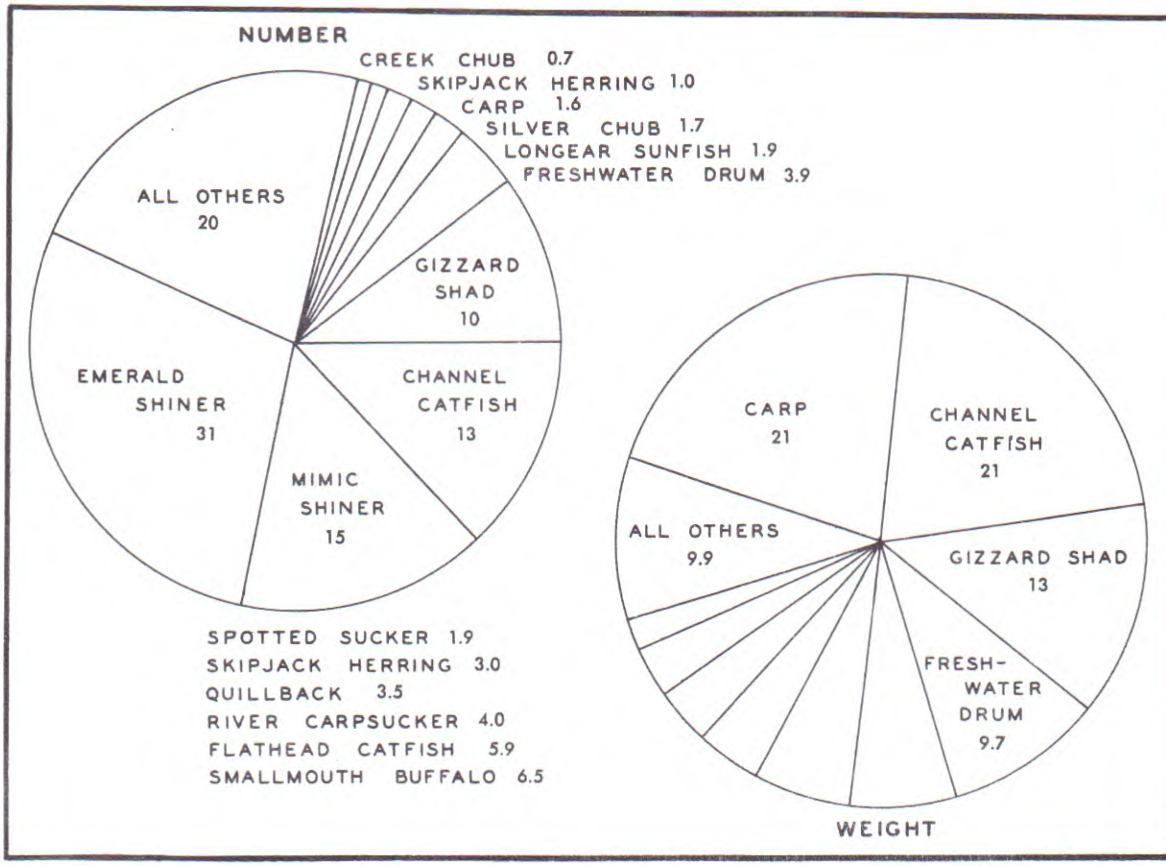


Figure 18 . Percentages, by numbers and weights, of all fishes taken by all methods between Ohio River Miles 300 and 400 (Section 4) during the three-year study period. Only the 10 most abundant fishes are listed separately; the others are combined.

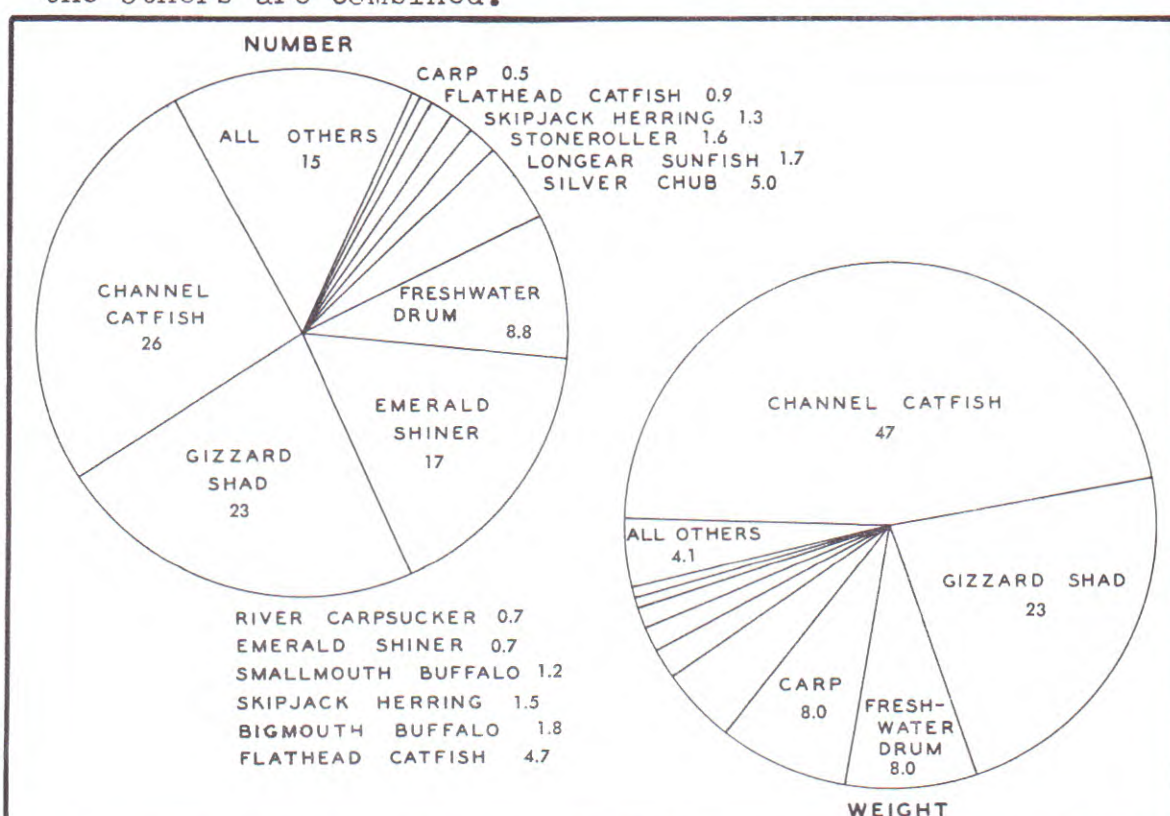


Figure 19 . Percentages, by numbers and weights, of all fishes taken by all methods between Ohio River Miles 400 and 500 (Section 5) during the three-year study period. Only the 10 most abundant fishes are listed separately; the others are combined.

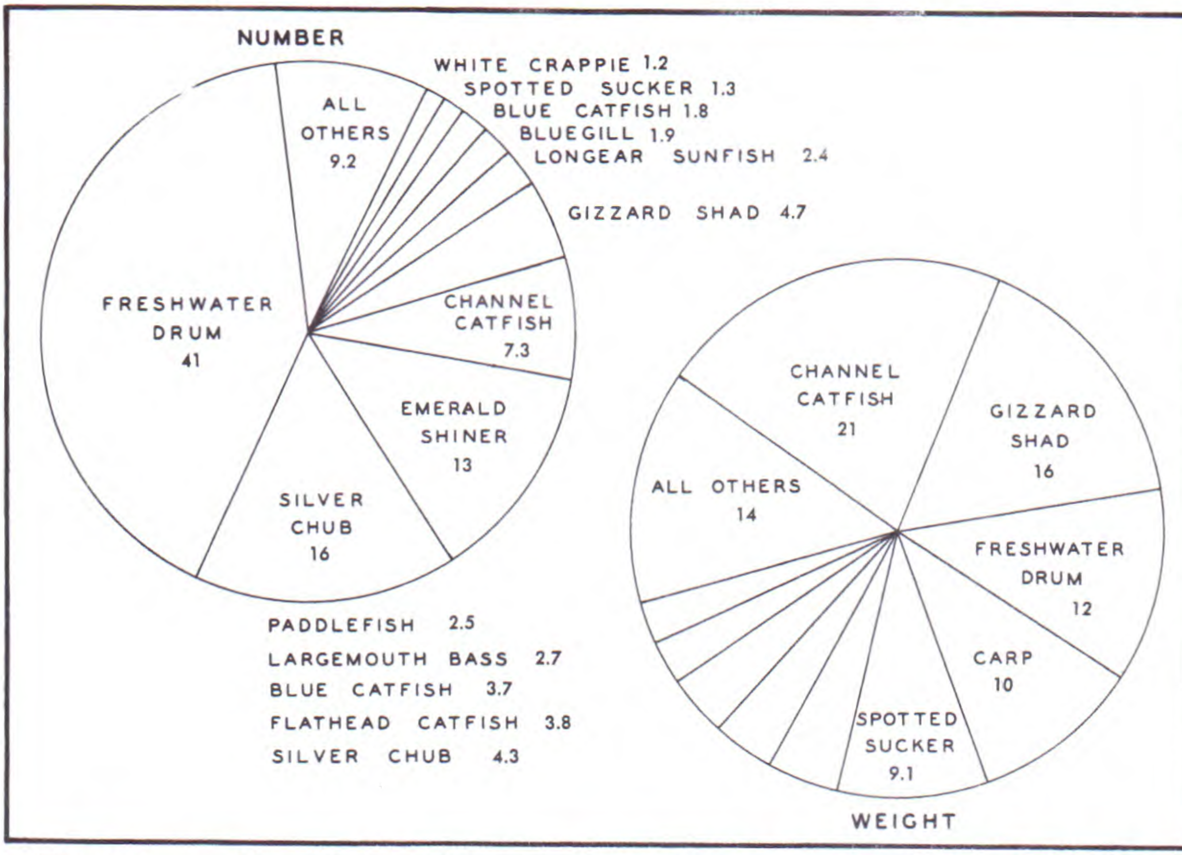


Figure 20 . Percentages, by numbers and weights, of all fishes taken by all methods between Ohio River Miles 500 and 600 (Section 6) during the three-year study period. Only the 10 most abundant fishes are listed separately; the others are combined.

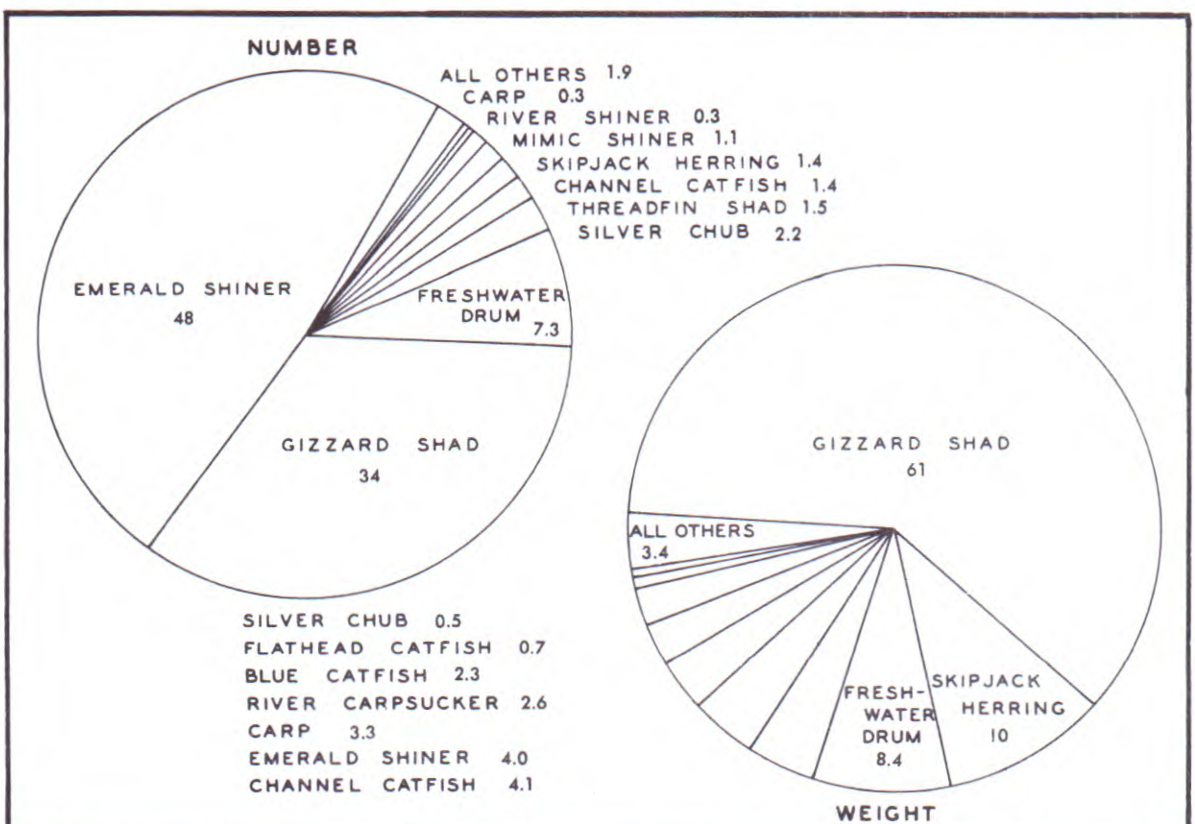


Figure 21 . Percentages, by numbers and weights, of all fishes taken by all methods between Ohio River Miles 600 and 700 (Section 7) during the three-year study period. Only the 10 most abundant fishes are listed separately; the others are combined.

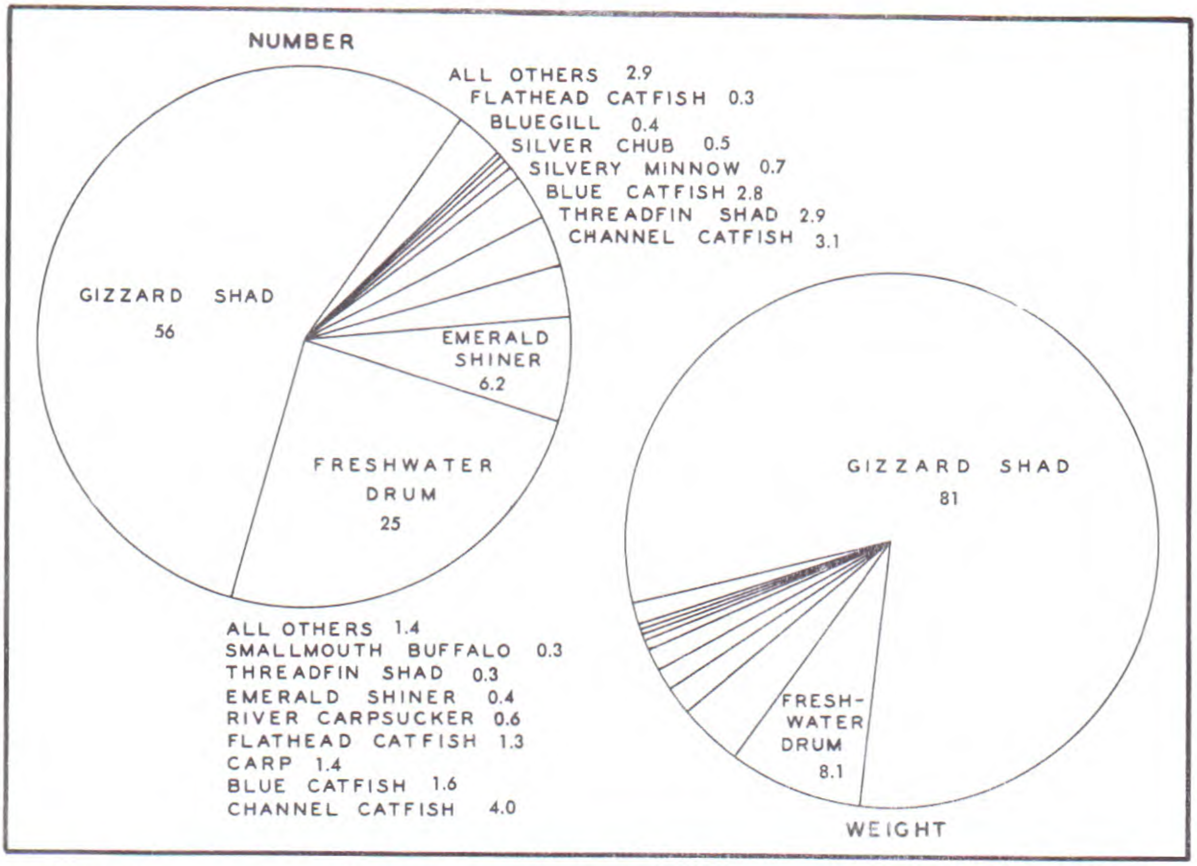


Figure 22 . Percentages, by numbers and weights, of all fishes taken by all methods between Ohio River Miles 700 and 800 (Section 8) during the three-year study period. Only the 10 most abundant fishes are listed separately; the others are combined.

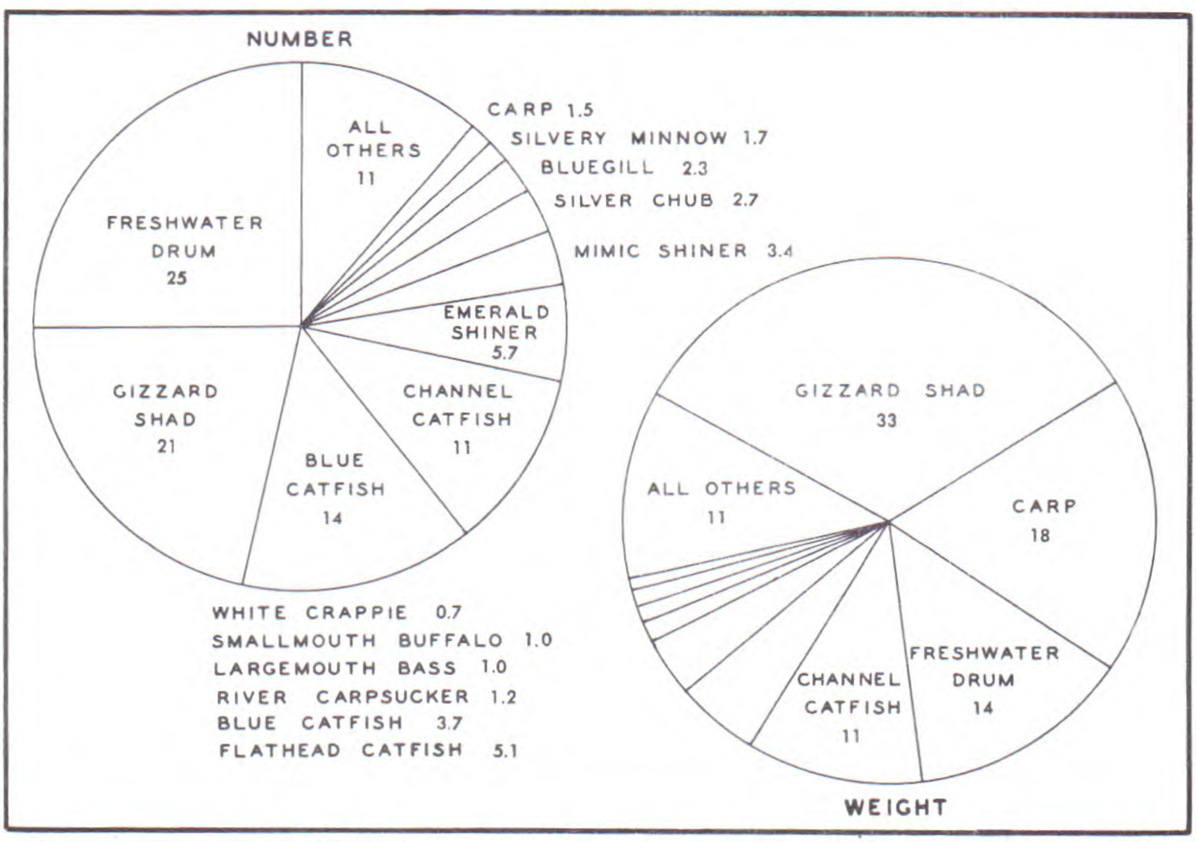


Figure 23 . Percentages, by numbers and weights, of all fishes taken by all methods between Ohio River Miles 800 and 900 (Section 9) during the three-year period. Only the 10 most abundant fishes are listed separately; the others are combined.

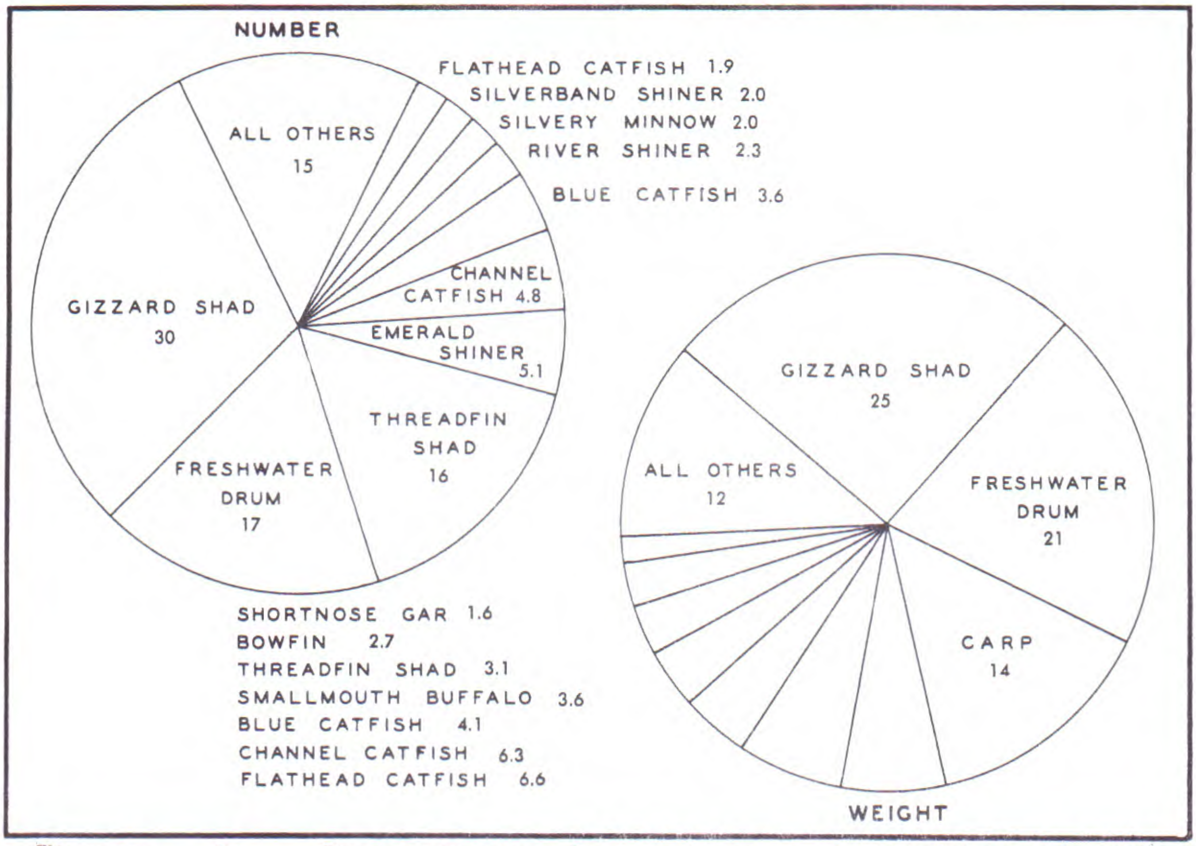


Figure 24 . Percentages, by numbers and weights, of all fishes taken by all methods between Ohio River Miles 900 and 981 (Section 10) during the three-year study period. Only the 10 most abundant fishes are listed separately; the others are combined.

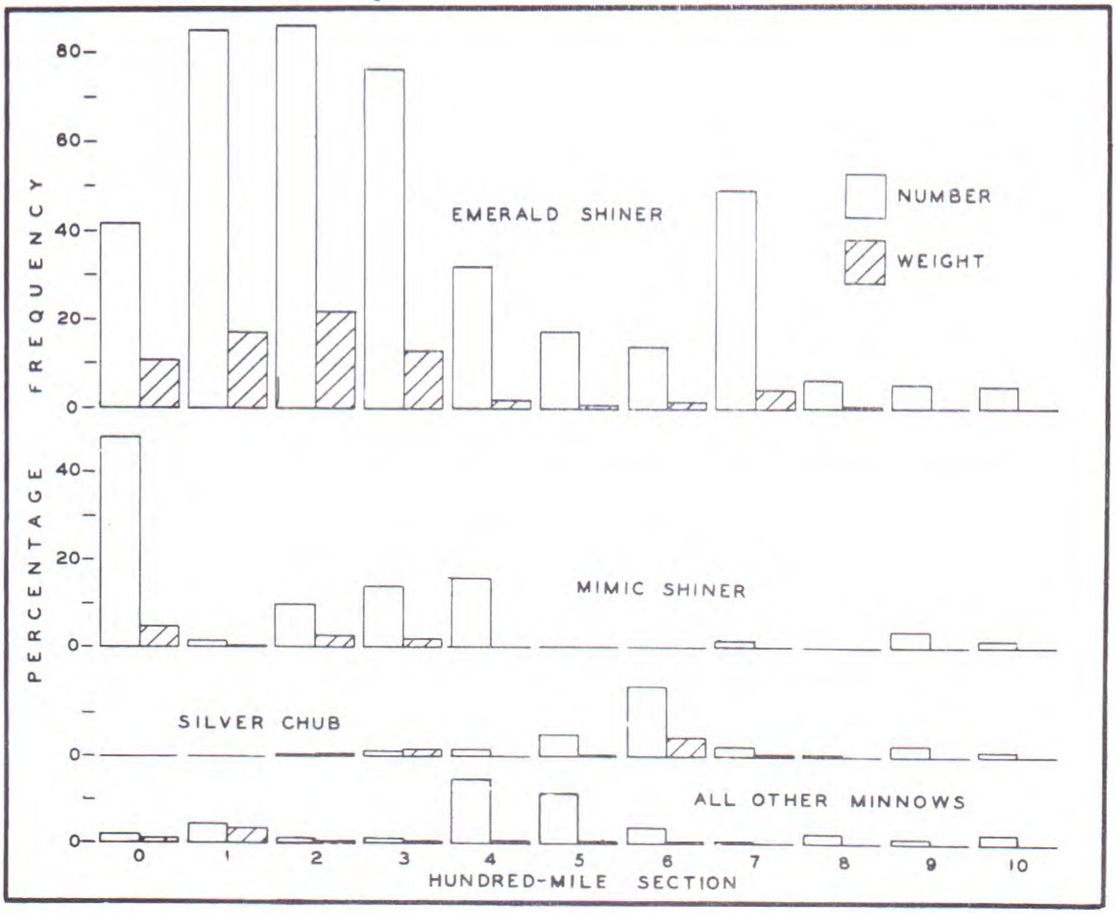


Figure 25 . Linear distribution by numbers and weights of various minnows over the length of the Ohio River (see text for explanation).

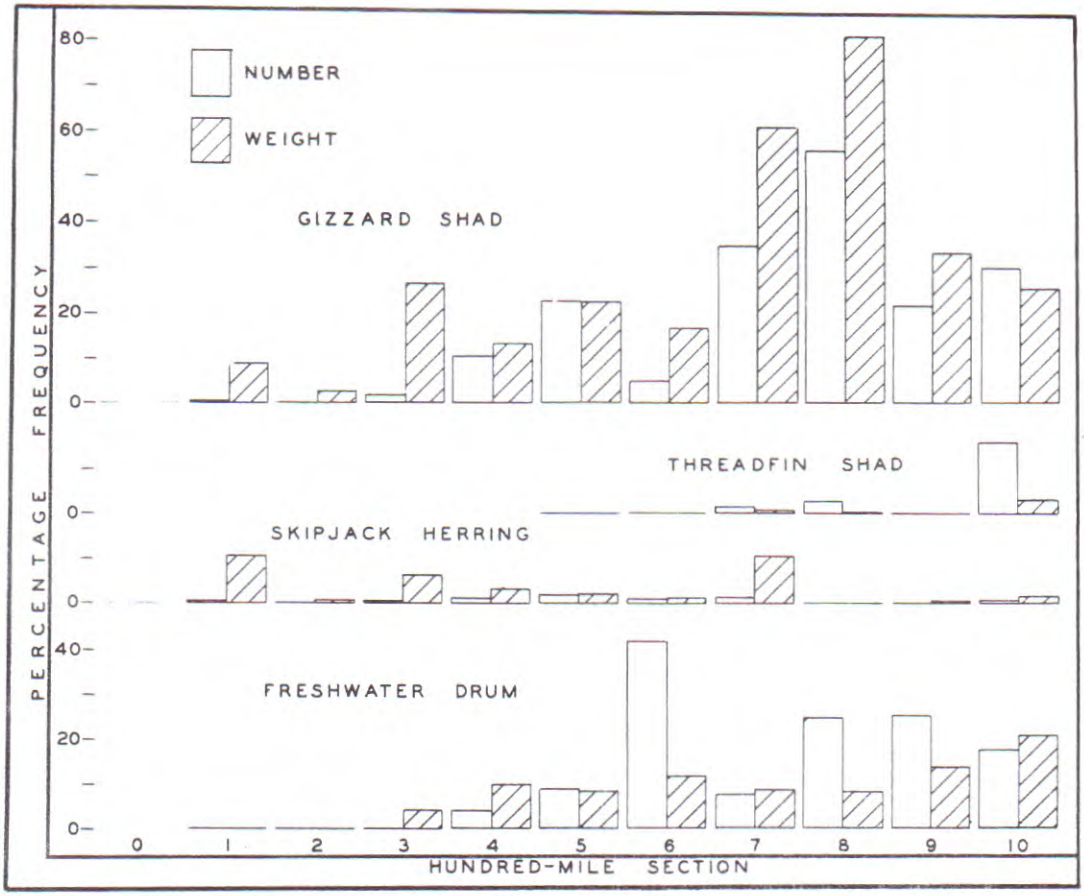


Figure 26 . Linear distribution by numbers and weights, of the gizzard shad, the threadfin shad, the skipjack herring, and the fresh-water drum over the length of the Ohio River (see text for explanation).

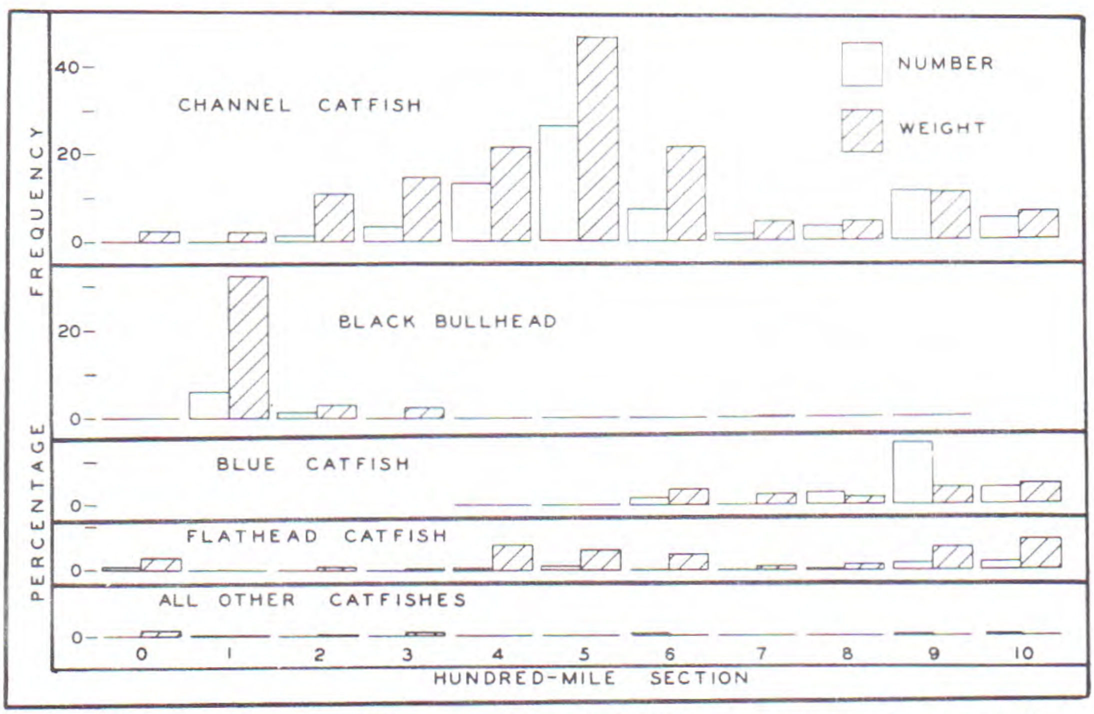


Figure 27 . Linear distribution, by numbers and weights, of catfishes over the length of the Ohio River (see text for explanation).

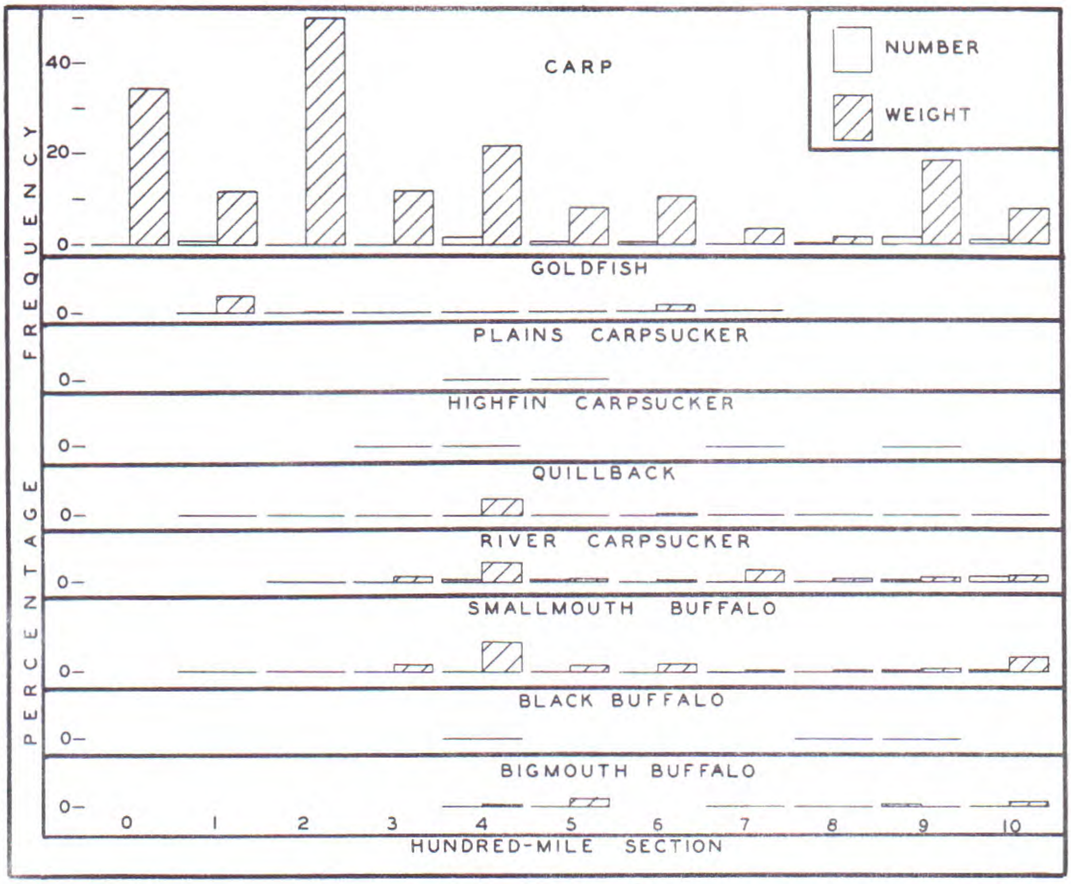


Figure 28 . Linear distribution, by numbers and weights, of deep-bodied suckers, together with the carp and goldfish, over the length of the Ohio River (see text for explanation).

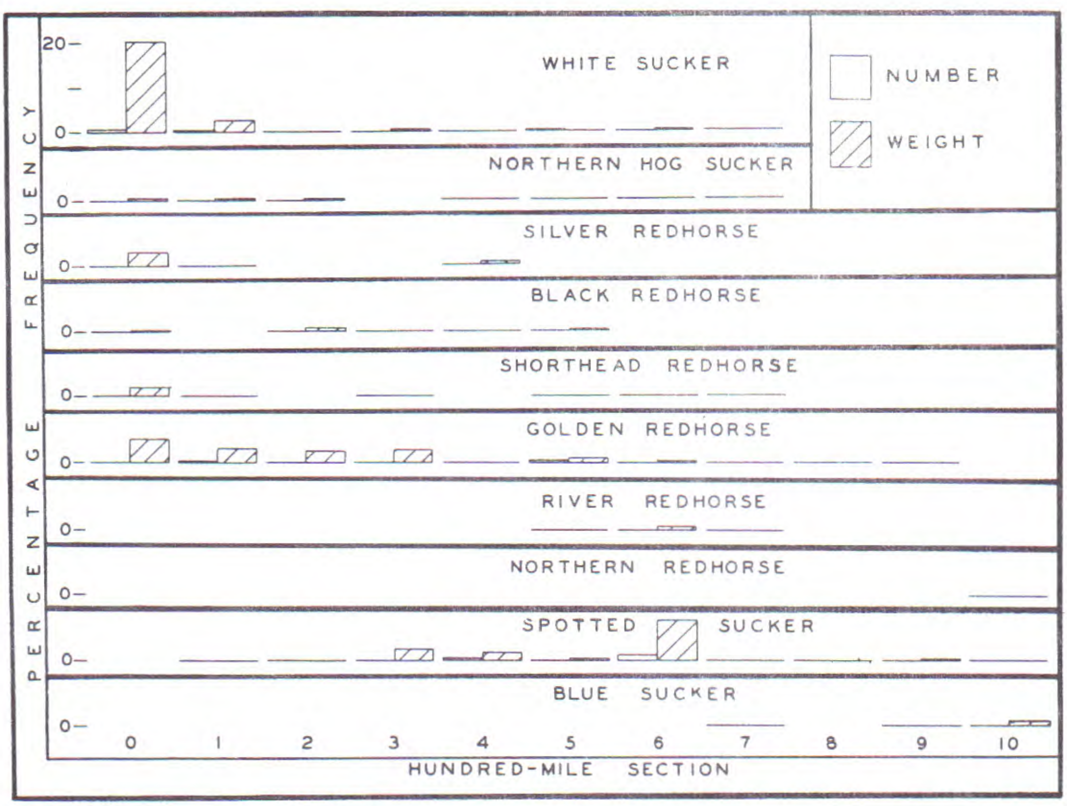


Figure 29 . Linear distribution, by numbers and weights, of round-bodied suckers over the length of the Ohio River (see text for explanation).

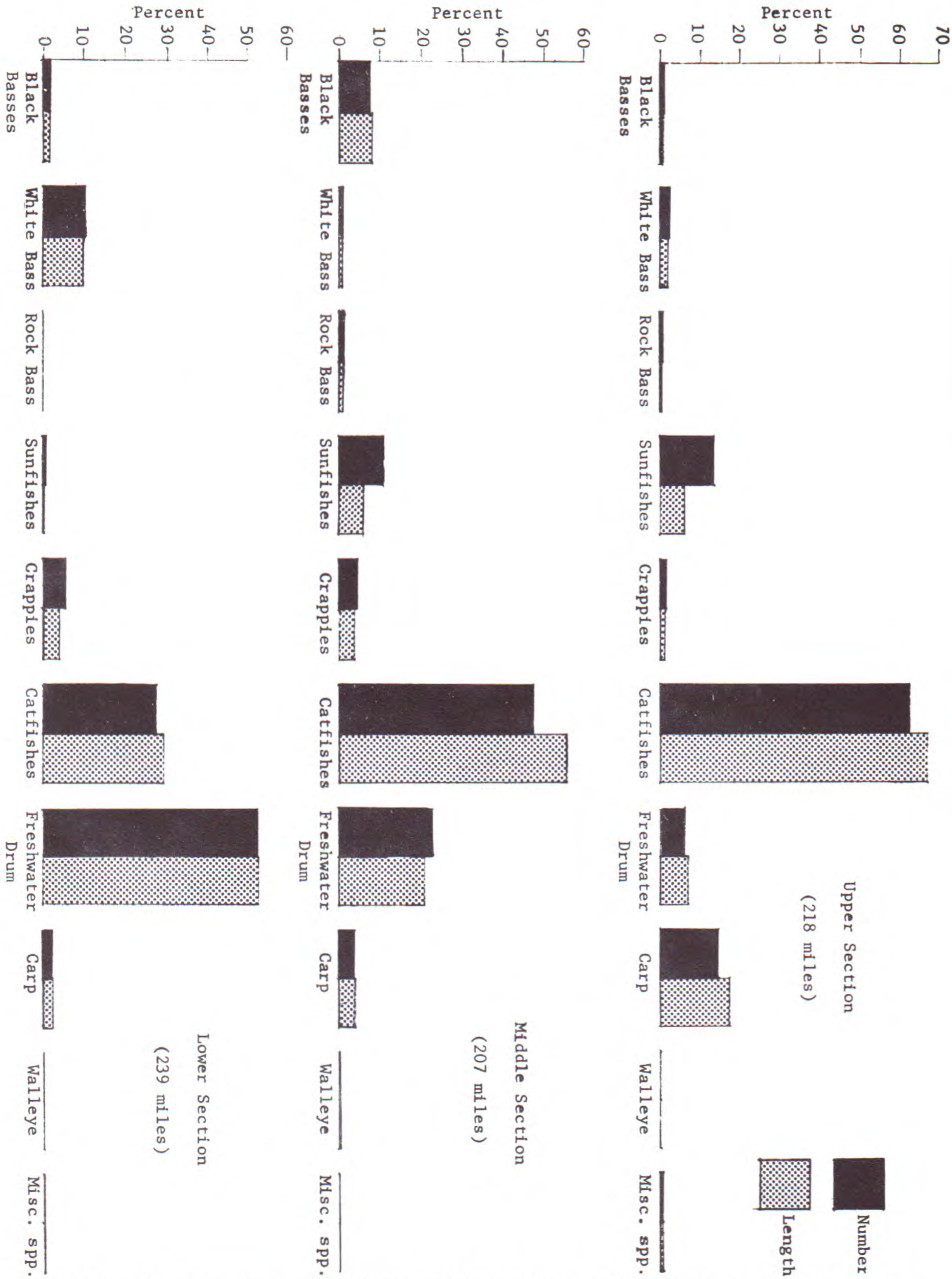


Figure 30. Percentage composition of the catch of 1,401 fishermen creel-censused on the Ohio River from March through October, 1957.

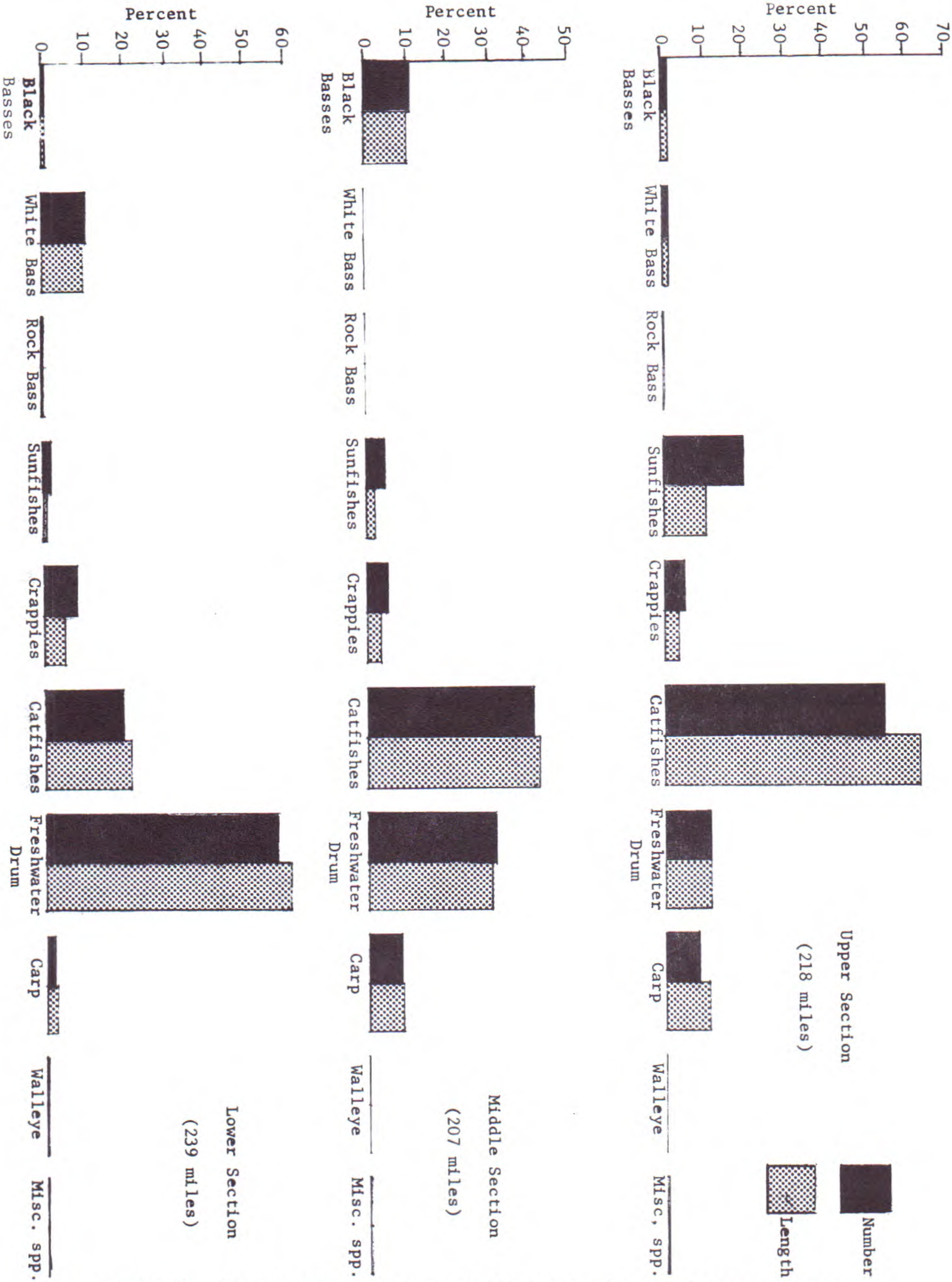


Figure 31. Percentage composition of the catch of 1,483 fishermen creel-censused on the Ohio River from March through October, 1958.

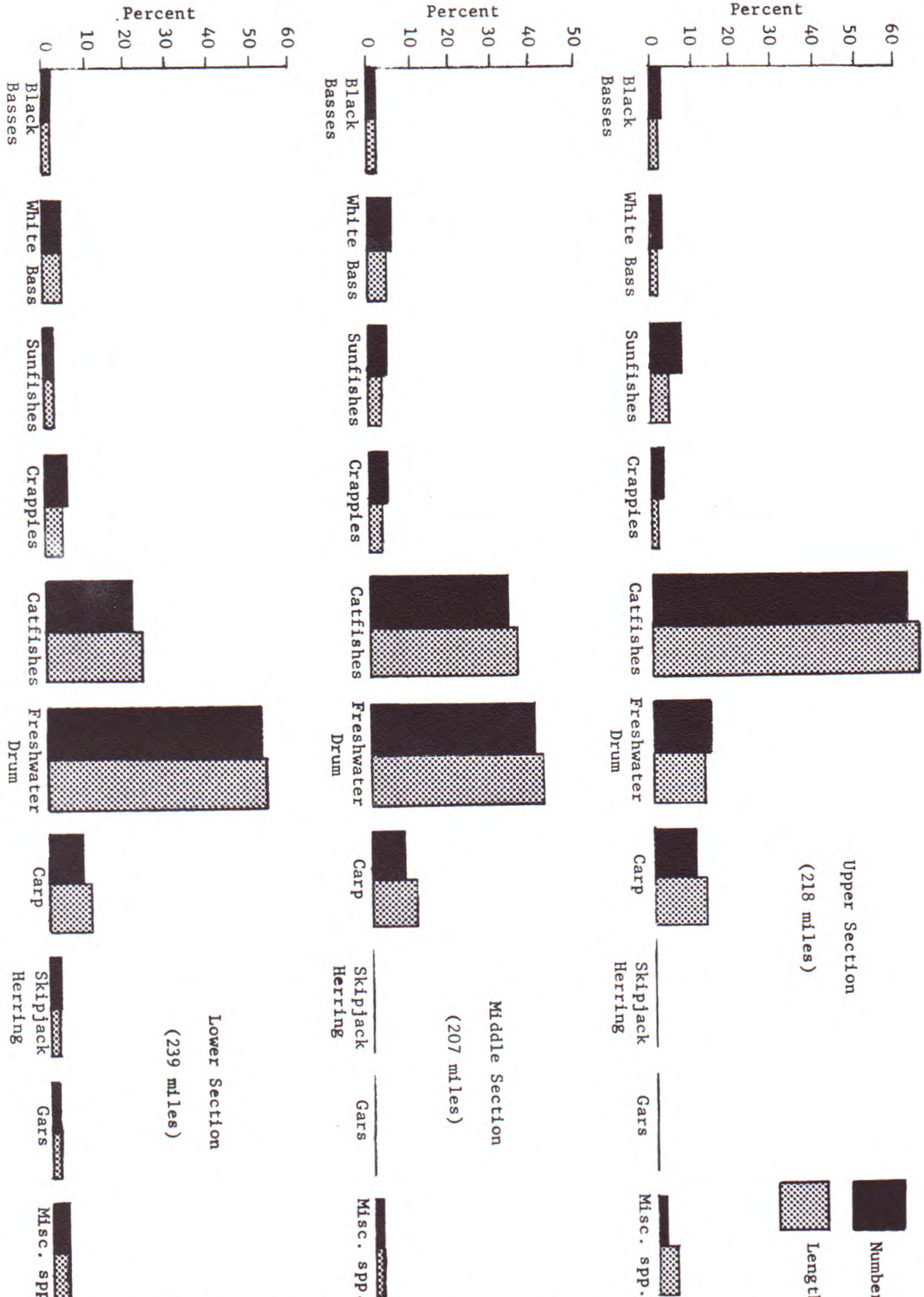
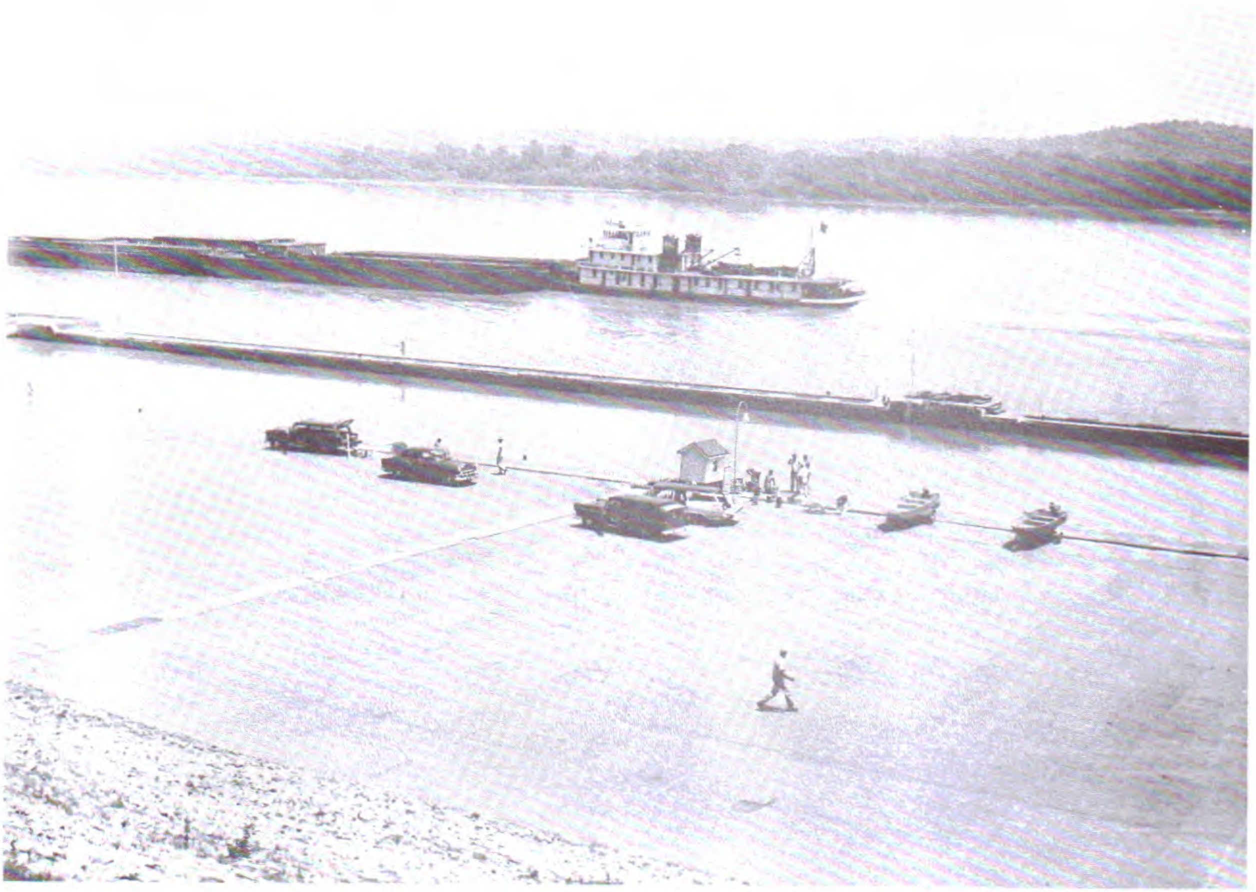
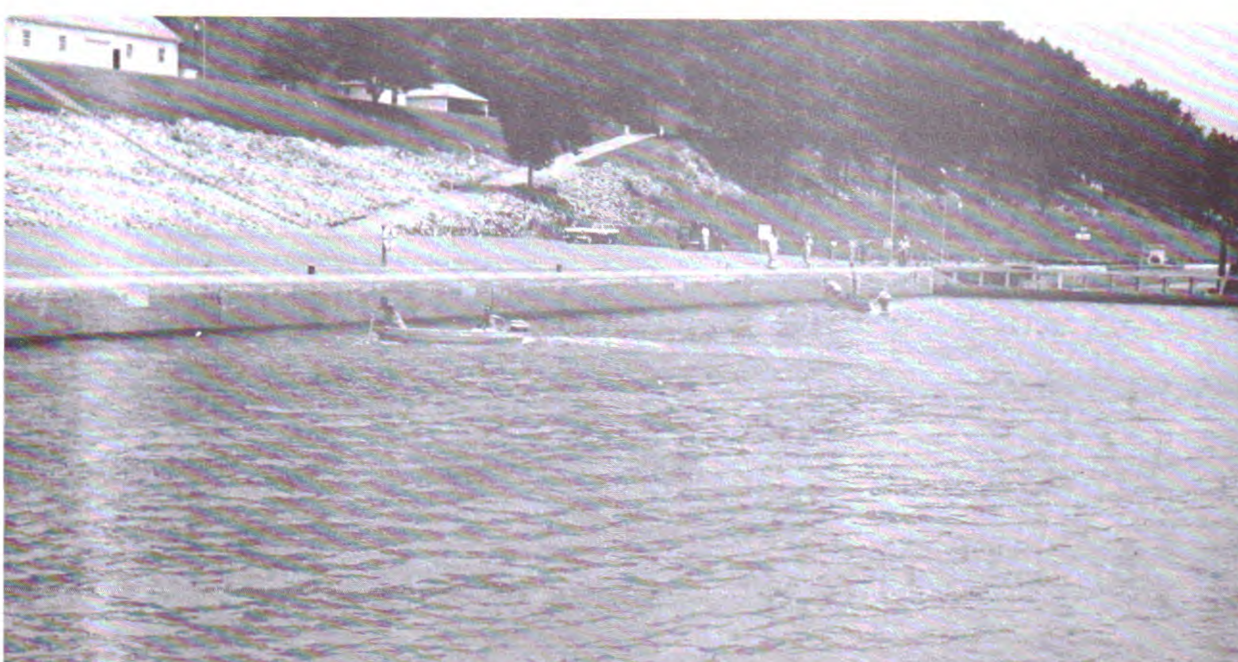
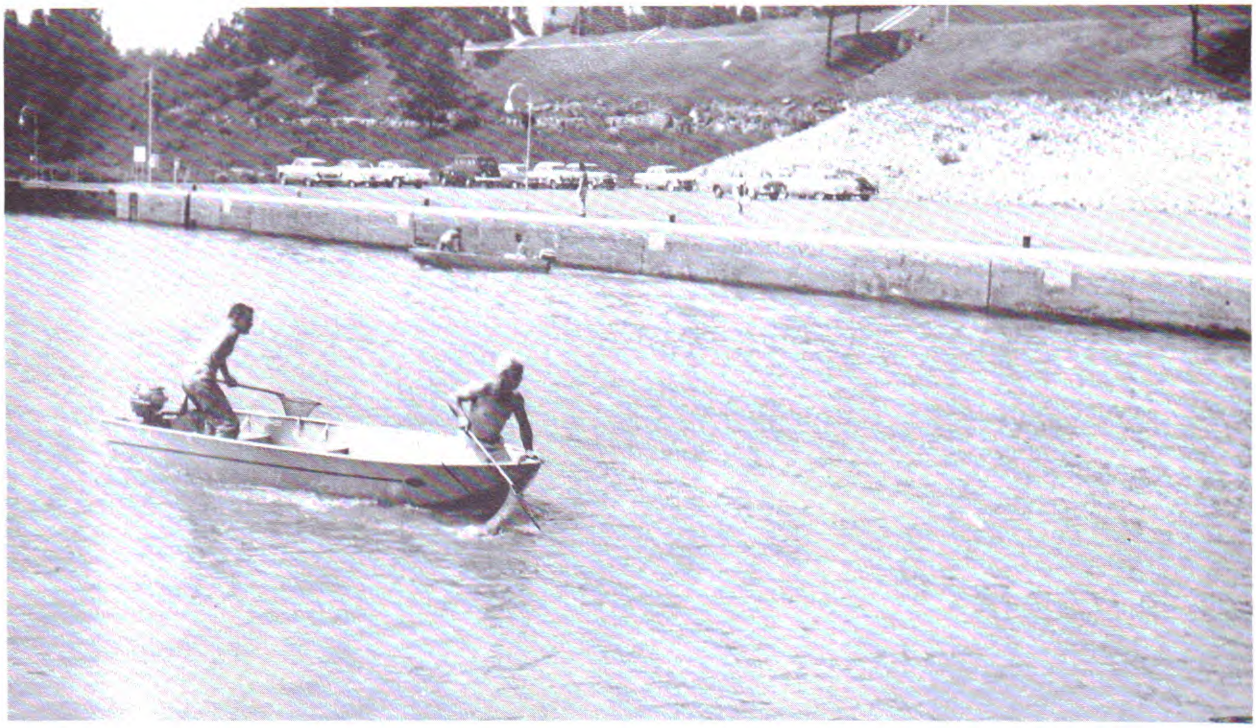


Figure 32. Percentage composition of the catch of 4,364 fishermen creel-censused on the Ohio River from April through October, 1959.

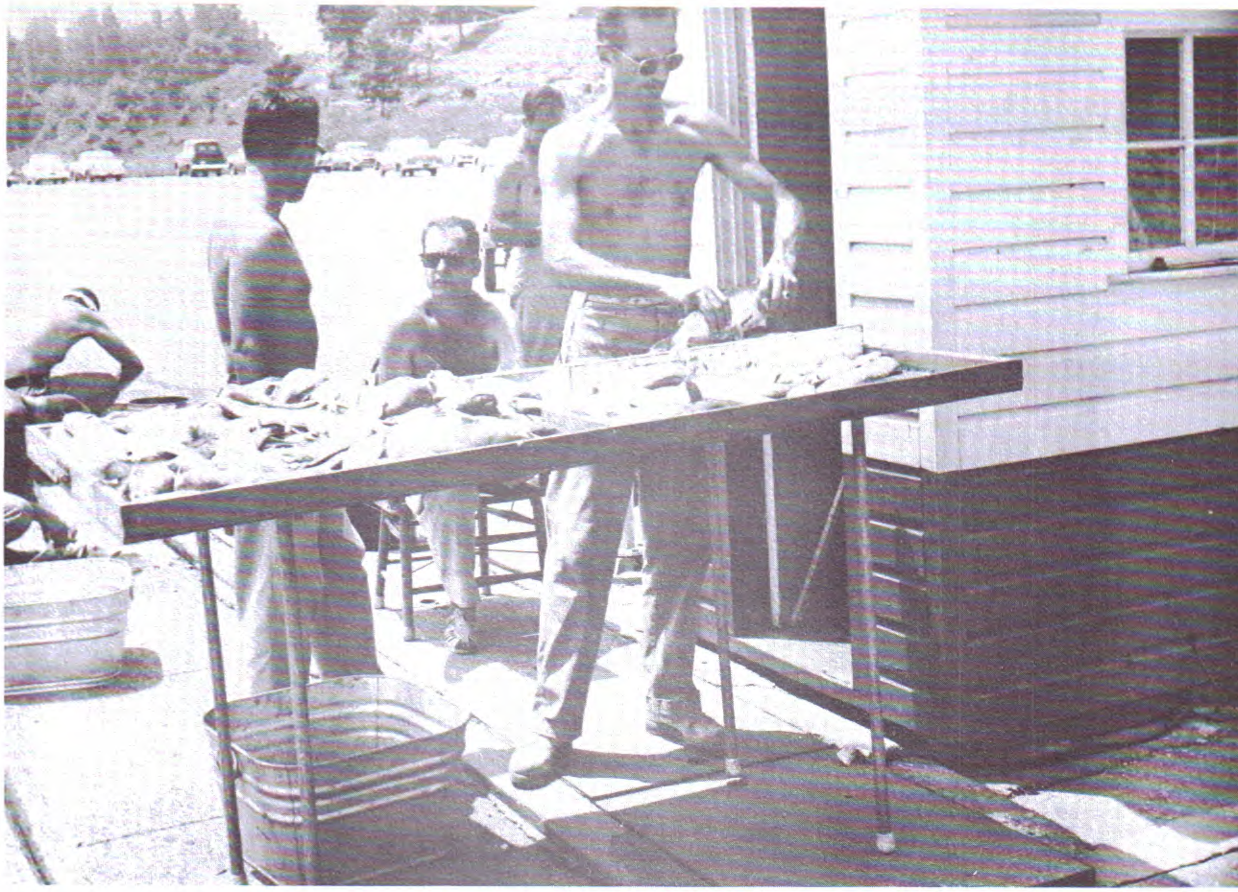


Field crew members gather at Lock 51, Golconda, Ill., on July 18, 1957, to sample the fish population. Rotenone is dispersed into the lock chamber.

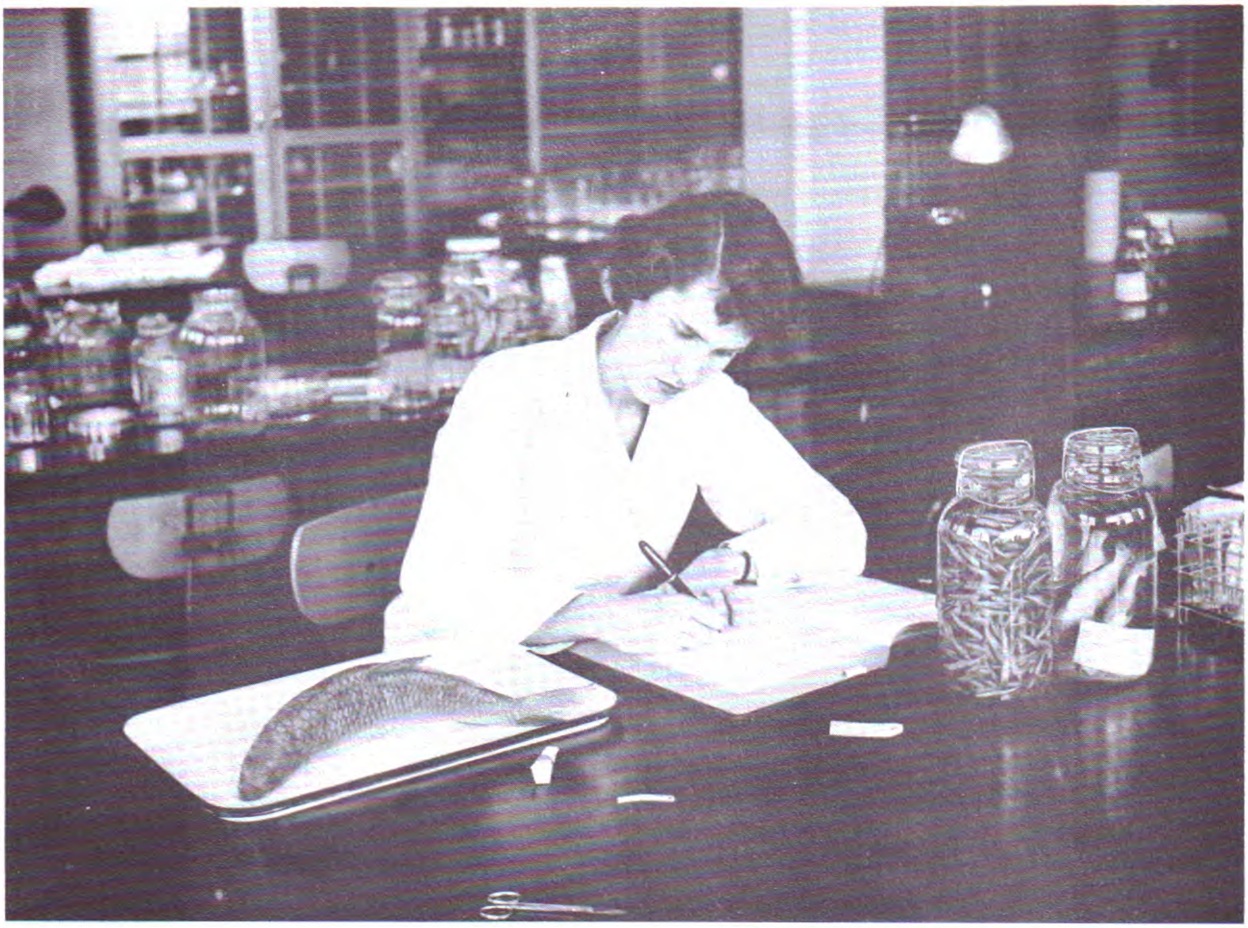




After applying rotenone, the field crew stands ready to pick up dead fishes as they rise to the surface. They work rapidly in order not to miss some species which tend to sink to the bottom after first surfacing.



The 334 fish recovered in this study were immediately counted, measured, and sorted as to species. After identification the fish are preserved before leaving the field location.



Back in the laboratory, the fishes are carefully catalogued. The preserved specimens then take their places on the laboratory shelves, for easy reference.