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THEODORE H. FRISON, *Acting Chief*

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The Fishes of Champaign County

A Study of the Distribution and Abundance of Fishes in Small Streams

BY

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and
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THE FISHES OF CHAMPAIGN COUNTY*

A Study of the Distribution and Abundance of Fishes in Small Streams

David H. Thompson and Francis D. Hunt

A careful account of the local and general distribution of the fishes of Illinois, their relations to their environment, and the function and relative importance of each species in the general system of aquatic life, was presented twenty years ago in a comprehensive work by Forbes and Richardson[1], which was based primarily on a state-wide ichthyological survey. In the present study the general methods employed in the former survey have been applied intensively to a small area, Champaign County, and use has been made of special methods which yield results more strictly quantitative. Inasmuch as there exist among the small stream systems of this county faunal differences comparable to those found among large stream systems, not only in Illinois but elsewhere as well, the intensive study of this restricted area has made it possible to formulate in a more precise manner some of the general conclusions previously reached by other workers on the distribution and abundance of fishes. The use of quantitative methods of collecting has made it possible also to arrive at new conclusions based on such data as may have passed unnoticed in a less detailed study or in streams too large to apply such methods.

Description of the Area

Champaign County is located in the east-central part of Illinois and is crossed by the 88th meridian and the 40th parallel. Measuring approximately 36 miles from north to south and 27.5 miles from east to west, the county has an area of 988 square miles. The topography varies from flat to slightly rolling land, the variations being due to two causes—glacial action and stream erosion. The average altitude is about 710 feet above sea level; a maximum of 860 feet is reached on the Champaign moraine and a minimum of 630 feet where the Salt Fork leaves the county.

*This study was carried on and completed under the direction of the late Stephen Alfred Forbes.

1. Forbes, S. A., and R. E. Richardson. "The Fishes of Illinois." Final Reports of the Illinois Natural History Survey, Vol. III, 1909.

During the Glacial Period, Champaign County was covered by two ice sheets, the Illinoian and the Early Wisconsin; and the otherwise monotonous topography of the county is broken by their terminal moraines, which commonly rise 50 to 100 feet above the intermorainal tracts, vary from one-half mile to three or four miles in width, and usually form the boundaries between the several drainage basins (Fig. 1). As the Early Wisconsin sheet receded, the various parts of the county were uncovered in the following order: first, the lower part of the

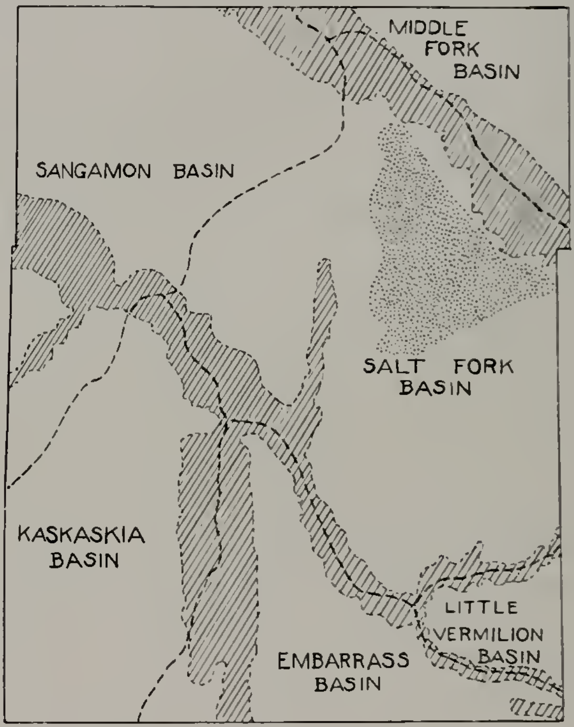

Fig. 1. Sketch map of Champaign County, showing watersheds (dotted lines), glacial moraines (cross-hatching), and unusually fertile area (stippling).

Sangamon basin; next, the Kaskaskia and Embarrass basins; then the upper Sangamon, Salt Fork, and Little Vermilion basins; and lastly, the basin of the Middle Fork of the Vermilion. The general aspects of the topography now are the same as at that time, and there has been no subsequent change in the hook-up of the drainage systems.[2] There are no outcrops of rock in the county, as it is covered with a layer of boulder clay ranging from 95 to 300 feet in thickness.[3]

2. Personal communication from Dr. M. M. Leighton, Chief, Illinois State Geological Survey.
3. Ill. Agr. Exp. Sta. Soil Report No. 18, "Champaign County Soils," 1918.

The soils of Champaign County are fertile and, taken as a whole, are more uniform than those of other counties of the state. Dark upland prairie soils make up 92 percent of the area of the county, and upland timber soils an additional 5 percent. Of the 92 percent of upland prairie soils, 73 is brown silt loam and 18 is black clay loam. Almost all of the upland timber soil is yellow-gray silt loam. The water-table in the county lies 45 to 60 inches beneath the surface and is generally more uniform in depth than in other counties.[4]

There is an area of about 50 square miles in the eastern part of the county in which the soil has a different history from that of the rest of the county and is unusually fertile. This area is drained by the East Branch of the Salt Fork and lies north of the town of St. Joseph. (See Figure 1.) The soil of this area was formed under water, and until this part of Illinois was settled, it was a marsh in which water-fowl abounded. Later, when ditches were dug, the marsh was reduced to a few ponds, and more recently it has been drained completely, but the organic matter that had accumulated under water has not leached away. The soil is highly calcareous and therefore rich in available plant foods; nodules of calcium carbonate occur throughout it and render it more alkaline than other soils of the county. An unusually rich fish fauna was found in the streams of this area, as will be shown in a later section.

Weather records for the past 26 years have been kept by an observer of the United States Weather Bureau at Urbana. The Weather Bureau station is near the center of the county and has an altitude of 743 feet. The mean annual temperature for the 26 years is 51.2° F. and the mean annual rainfall 34.26 inches. The mean temperature for 1928 alone was 51.4° F. and the total rainfall 32.96 inches.

The mean monthly temperatures for 1928 and for the past 26 years are as follows:

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1928	27.5	32.2	39.6	46.8	61.8	65.4	74.8	74.0	61.8	57.2	42.4	33.4
Ave. 26 yrs.	25.9	27.7	40.2	50.4	61.0	70.3	74.7	72.9	66.2	54.1	41.7	29.3

The mean monthly rainfalls for 1928 and for the past 26 years are as follows:

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1928	2.18	2.28	1.45	3.16	2.48	4.65	3.59	2.77	3.65	2.34	1.88	2.53
Ave. 26 yrs.	2.12	1.78	3.38	3.74	3.94	3.16	3.01	3.44	2.98	2.38	2.13	2.20

DESCRIPTION OF THE STREAMS

Six streams have their headwaters in Champaign County: the Sangamon River, the Salt Fork and the Middle Fork of the Vermilion River, the Embarrass (pronounced Ambraw), the Kaskaskia (otherwise known as the Okaw), and the little Vermilion. The headwaters of

4. Personal communication from Mr. E. A. Norton, Assistant Chief, Soil Survey.

these six streams interlace except as they are separated by glacial moraines (see Figure 1). The drainage area in square miles at the point where each stream leaves the county is as follows: Sangamon 388, Salt Fork 307, Middle Fork 241, Embarrass 106, Kaskaskia 98, and Little

Fig. 2. Sketch map of Illinois, showing the location of Champaign County with respect to stream systems. The dotted line indicates the boundary of the unusually fertile area discussed in the text (page 50).

Vermilion 28. Other small streams flow out of the county, but they soon join one or the other of these six larger ones. The relation of these headwater streams to the larger streams of Illinois is shown in Figure 2.

While fishes in the headwaters of the Salt Fork may be but 2 or 3 miles overland from fishes in the headwaters of the Sangamon, they are more than 1,200 miles apart by water.

Because of the essential flatness of the county, most of the smaller streams have been straightened and deepened by dredging. This dredging has tended toward greater uniformity of environment but has not changed appreciably the kinds of fishes present nor their general distribution within the streams. However, dredging has an effect on the minutiae of their distribution and, less obviously, on their abundance. The cycle of change may be summed up as follows:

A brook meanders across a pasture with alternate gravelly riffles and vegetation-bordered stretches of mud and sand; is slowed down as it enters pools about the roots of trees in a patch of woodland; or is

Fig. 3. View of Sangamon River near Mahomet.

scattered into a dozen channels as it passes through a bit of marsh choked with willows and cat-tails. Thus the stream is well differentiated into a variety of situations, each with its own characteristic fishes. A dredging machine goes past and we have, instead, our brook flowing along a deep groove in the earth, with dirt piled in a high ridge on each side, of uniform width and grade, and uniformly denuded of every shred of vegetation. There are no more riffles, no shaded pools, but only constantly flowing silt-laden water. Now, for a few weeks or months, our fishes become literally the "mere ghosts" of their former selves. Owing to the lack of light they all fade to a uniform paleness. Since their food is destroyed, their bellies shrink, and their heads assume a prominence disproportionate to their customary aspect. But soon the process of redifferentiation begins. Gravelly riffles begin to form, with long stretches of sluggish water between. A few rains scoop out deep holes where the channel is narrowed by bridge abutments. Small drifts of debris furnish cover for fishes that seek it, and offer a richer spot for the beginnings of rooted vegetation than naked glacial till. In a year or two we see a heavy growth of weeds on the banks of the ditch and overhanging the water. A little later a sprinkling of willow and cottonwood appears, and in the water a fringe of *Elodea*, water cress, water smartweed, *Myriophyllum*, and many other coarse aquatic plants. At the end of 20 or 30 years we find that our brook is again something like its former self. It has gravelly riffles, meanders back and forth within its narrow confines, is choked by dense beds of aquatic plants.

Fig. 4. View of Kaskaskia River near Bondville.

At some places it is open to the sky, but at others it is thickly overhung by an ever-crowding thicket of willows and other small trees. Deep, shaded pools are also found about the roots of these newly grown trees. The vegetation checks the flow of water; the ditch fills up with silt from the fields; and then the dredging machine comes plodding up the stream again.

Dredge ditches showing this cycle of change are numerous in the county, and examples of all the different stages can be found within a single stream system such as the Kaskaskia. When the fishes of an old ditch are compared with the fishes of a new ditch, no outstanding difference is seen except that certain vegetation-loving forms, such as the pirate-perch and the grass pike, are temporarily absent in the new ditch. As for the rest of the fishes, we get about the same numbers and about the same proportion of the different species.

The slope of headwater streams in the county is commonly 10 to 15 feet per mile. Farther downstream the usual slope is 3 to 5 feet per mile. While the slope of one stream may be somewhat greater than that of another of the same size, the result is not to produce new kinds of aquatic environment but only to vary the proportion of uniform riffles and uniform sluggish reaches. The three larger undredged streams of the county, the Sangamon, the Middle Fork, and the Salt Fork, are very similar and offer to fishes almost exactly the same variety of habitats.

The kind of bottom which a stream has in Champaign County is primarily a function of the rate of flow of the water. The stream

Fig. 5. View of Camp Creek near Seymour.

channels are cut in glacial till, which is made up of particles of many sizes, from clay whose particles are 0.0002 inch or less in diameter up to boulders 2 feet across. Owing to the sorting power of water, nothing but rocks and boulders will be found in the swiftest water; pebbles and rocks on ordinary riffles; gravel and sand in smoothly flowing stretches; while the silt and clay is carried along and dropped in deep, wide places and eddies and wherever the movement of the water is checked. The kind of bottom determines very largely the kind and amount of food organisms for fishes and is thus an important factor in their distribution. While rate of flow and kind of bottom are closely related causally, more fishes seem to distribute themselves more of the time according to current than according to kind of bottom.

Both direct and indirect evidence has been accumulated which shows that in streams of the same size there occur parallel variations in physical characteristics, such as temperature, dissolved oxygen, hydrogen-ion concentration, turbidity, ice conditions, flood conditions, kind of bottom, depth, vegetation, and available fish food.

Permanency of flow is a factor of prime importance to the fishes of small streams. The point above which a stream is reduced to a series of shrunken pools in dry weather varies from 2 to 10 square miles of drainage area, depending on the lay of the land, kind of soil, drainage improvements, etc.

Stream size, in this paper, has been expressed in square miles of drainage area. A calculation based on the average annual rainfall, as measured by the U. S. Weather Bureau at Urbana, and on the average run-off of various county streams, as measured by Mr. R. A. Norton, engineer of the U. S. Department of Agriculture, gives an average annual flow of almost exactly one cubic foot per second per square mile. This may be used as a rule of thumb to translate statements of drainage area (square miles) directly into terms of average annual flow (cubic feet per second), since the two are numerically equivalent. From the point of view of this paper a precise statement of the average annual flow of the various streams would be valueless because it represents a stage of water which is attained only occasionally as a stream is rising to, or receding from, a flood. The actual flow for all but a very small fraction of the total time is either more or less than the annual average.

Pollution by sewage, which is one of the most important factors affecting the variety and abundance of fishes in certain streams of the county, will be discussed separately (pp. 50-57).

The oxygen content of unpolluted streams in Champaign County varies from about 6 parts per million up to super-saturation due to the production of oxygen by chlorophyll-bearing plants in sunlight.

The pH varies from 6.5 to 8.3, with most readings between 7.2 and 7.8.

The turbidity, naturally, is extreme during freshets; but during ordinary or low stages of water, small objects on the bottom commonly can be seen through a foot of water in winter and 3 to 6 inches in summer, the comparative clearness in winter probably being due in part to the inactivity of the fishes and the lesser development of the plankton. The clearest stream in the county is the most heavily polluted part of the Salt Fork, and its clearness is probably due to the almost complete absence of fishes. Accurate measurements of turbidity were made at the beginning of this study but were soon discontinued because in many cases the roiliness was directly traced to ditching machines, bridge building, livestock wading in the water, and other temporary disturbances.

Temperatures in local streams vary from freezing in winter to 90°F. in unshaded stretches in mid-summer, although the variations, of course, are not quite so abrupt nor so great as in the air. Most fishes are sedentary and do not feed or grow much when the water is at or near the freezing point. The growing season for most of the local fishes is probably about seven months—from sometime in March or early April until October or early November. Usually for a month during every winter, the streams are completely frozen over except for the riffles, and on the more slowly moving stretches ice may form to a thickness of 12 or more inches. In summer, there is great variation in the temperature of the water at different places in the streams, depending on the amount of shade.

The Middle Fork, the Salt Fork, and the Sangamon, before leaving the county, form narrow flood plains which may reach a quarter-mile or more in width. At ordinary or low stages of water each of these streams flows between steep earth banks, 4 to 8 feet below the flood plain, but at least once each year the water rises 10 or 15 feet and covers the flood plain.

The common coarse aquatic plants of the county have been observed, and specimens have been identified by Mr. L. R. Tehon, Botanist for the Illinois Natural History Survey. A list follows:

Cladophora glomerata—streamers attached to stones of riffles and rapids of the larger streams.

Cladophora crispata—forming mats in quieter water of streams and ponds.

Fissidens Julianus—moss. On top of submerged rocks in the swiftest water of the Middle Fork and Sangamon.

Equisetum hiemale—horse tail. On ditch banks, etc.

Typha latifolia—common cat tail. In mud and shallow water at the headwaters of small streams.

Sparganium sp.—bur reed. In mud and shallow water along small streams.

Potamogeton americanus, P. heterophyllus, P. zosterifolius, and P. pusillus—Submerged in small flowing streams.

Sagittaria heterophylla—arrow leaf. Muddy banks of streams.

Elodea canadensis—In small flowing streams.

Grasses and sedges of various species. In and along streams.

Scirpus validus, S. fluviatilis, and S. atrovirens—bull rushes. In and along streams.

Lemna minor—duck weed. Floating and on muddy margins.

Spiradela polyrhiza—duch weed. Floating and on muddy margins.

Juncus spp.—rushes. On muddy banks of streams.

Salix spp.—willows. Along streams of all sizes.

Rumex crispus—common dock. In or near the water in many situations.

Rumex verticillatus—swamp dock. In swampy places.

Polygonum Hydropiper—water smartweed. Abundant in sluggishly flowing streams and ditches of small size.

Nymphaea advena—yellow water lily. In sluggishly flowing pools.

Ranunculus aquatilis—butter cup. Muddy banks.

Radicula Nasturtium-aquaticum—water cress. Small flowing streams.

Collitriche sp.—water starwort. Small flowing streams.

Jussiaea diffusa—primrose-willow.

Myriophyllum heterophyllum—squirrel tail. Shallow water and muddy banks of small streams.

Dianathera americana—water willow. Gravelly and rocky shallows and shores of small swift rivers.

Cephalanthus occidentalis—button bush. Swampy flats along the larger streams the county.

Ambrosia trifida—giant ragweed. Fertile banks and flood plains.

Bidens frondosa, B. cernua, and B. spp.—Spanish needles, beggar's ticks. Along streams.

Methods and Equipment

In planning this quantitative study of Champaign County fishes it was foreseen that the important sources of error would likely arise in the collection of the fishes and the distribution of the samples. As has been stated before, all of these streams are small, with depths ranging from an inch to 3 feet at ordinary stages of water. Most kinds of fishing apparatus are highly selective and particularly so if any movement or other reaction of the fishes is necessary for their capture. It was decided that a single piece of fishing apparatus would give most uniform results, and for this a "common-sense" minnow seine was chosen, 10 feet long and 4 feet wide, with meshes 1/6 inch square. Of the 132 collections 127 were made with this seine, and the other 5 with an inch-mesh seine, 75 by 6 feet, which took only larger fishes. In subsequent treatment of the data the collections made with the latter seine were properly weighted and made to apply only to the larger fishes. Several years of experience with small seines in many kinds of situations, as well as continual estimation and measurement of the area covered per haul, indicated that in such small streams, with the same persons fishing in the same manner, a 10-foot minnow seine took fishes efficiently from 10 square yards, a 12-foot minnow seine from 15 square yards, and a 30-foot minnow seine from 50 square yards. The 75-foot inch-mesh seine used was estimated to include 100 square yards. The 1/6-inch mesh used in this study took fry of the smallest sizes identifiable.

Another factor of great importance in making such quantitative studies of fishes is the skill and efficiency with which the equipment is used. The success of this phase of our work is due to the ingenuity and skill of the junior author in gathering up, not a few of the fishes, but almost all of them from a given area. Without someone who, through long experience, is thus able to collect fishes from the different situations efficiently, it would be practically useless to attempt quantitative work.

The collections are distributed over all the seasons of 1928 from early spring to late autumn, and for this reason the data not only present the average of a year's collecting but also indicate many instances of changes in detailed distribution of species.

While an attempt was made to do the collecting at ordinary stages of water, it nevertheless happened that the collections in some streams were made at higher stages and, hence, at considerably greater dilutions than in others which were abnormally low. The order of the stream systems according to their average stages of water when the collections were made, from greatest dilution to greatest concentration, is as follows: (1) Embarrass, (2) Kaskaskia, (3) Salt Fork, (4) Little Vermilion, (5) Sangamon, (6) Middle Fork. Differences in number of fishes per unit area due to differences in dilution may be as much as 50 to 75 per cent between the extremes, that is, between the Embarrass and the Middle Fork stream systems.

An effort was made to make collections as closely as possible proportional to water area. The following tabulation shows the number of collections and the total area collected over in streams of different sizes:

Stream size in square miles of drainage area	Number of collections	Total area of collections in square yards
½-1	5	140
1-2	5	97
2-4	7	345
4-8	21	985
8-16	22	1230
16-32	15	938
32-64	19	1670
64-128	12	1325
128-256	13	1360
256-512	13	1450

While smaller streams were sampled at intervals of 5 to 10 miles, larger streams were sampled every 1 or 2 miles. Collecting points were marked on our field maps in the laboratory prior to the actual collecting. We did not travel about over the country until we found a likely spot and then stop and fish. When a collecting point was reached our attention was directed primarily to making a composite collection representing proportionally, as far as possible, the various aquatic situations presented.

Two to four men made up the field party and travelled to and from the laboratory by automobile. The work was much facilitated by the large amount of paved highway in this county.

Since most of the collections were made near bridges, the locations were recorded by township, range, and section numbers as well as by name of stream and distance and direction from the nearest town, so that it will be possible to duplicate the sampling in the future if it is found desirable. Accession numbers were entered on the field map, which was a Soil Survey map cut into 12 pieces and mounted on pages in the field notebook.

The drainage areas of the various streams at each of the 132 points of collection were determined by marking out the drainage areas on U. S. Geological Survey and Illinois Soil Survey maps and measuring with a planimeter. While it is possible to express stream size as average annual flow in cubic feet per second, it has been thought best to leave it in square miles of drainage area (see above, p. 12).

The 132 quantitative collections of fishes made within the county in 1928 included 28,905 specimens, an average of some 220 fishes per collection. The area included in individual collections varied from 10 to 250 square yards, but 82% of the collections were made in areas of more than 40 square yards. Before statistical treatment of the data was begun, all collections were reduced to numbers per 100 square yards.

One of the reasons for doing this intensive work was to permit a direct comparison with earlier collections made in Champaign County. This county was collected over at that time as thoroughly as any other part of the state, with collections distributed as follows: 1 in 1882, 3 in 1885, 1 in 1892, 2 in 1898, 22 in 1899, 3 in 1900, and 8 in 1901. The distribution of both recent and older collections by stream systems is as follows:

Stream system	Square miles of drainage area in the county	Number of collections	
		1882-1901	1928
Salt Fork	346	24	52
Sangamon	227	8	32
Embarrass	138	3	20
Kaskaskia	168	2	15
Middle Fork	69	3	9
Little Vermilion	40	0	4
Total	988	40	132

The net most generally used was treated for preservation with a light coat of pine tar, which was applied by diluting the tar with an equal amount of acetone.

Two or three square 5-gallon malted-milk cans with a 5-inch opening were used for storing collections temporarily in a strong formaldehyde solution. The fishes were dumped directly from the net into a 14-quart pail about half-full of strong formaldehyde solution, in which they died with the fins extended, the mouth and gills closed, and the body straight, making excellent specimens. The formaldehyde kills and hardens them so quickly that scarcely a scale is lost or a fin tattered, and the contour of the body is not in the least distorted. The latter fact is imporant because the confusion in the identification of certain groups, such as the genera *Carpiodes* and *Ictiobus*, seems to be due primarily to distortion in preserved specimens. Miscellaneous small bottom animals were thrown into the pail with the fishes and taken to the automobile or boat, where all were transferred to a bag made of a good quality of cheese cloth and measuring 12 by 17 inches. In order to avoid getting the formaldehyde on our hands, the transfer of the fishes, *etc.*, from the pail to the bag was made by putting the empty bag into the malted-milk can with the mouth of the bag lapped back over the lip of the can and fastened with a cord or a heavy rubber band. The bucket was emptied into the mouth of the bag, a slip of paper dropped in with an accession number corresponding to a page number in the loose-leaf field notebook, the mouth of the bag tied, and the whole stored in strong formaldehyde in a can of the kind described above. All the fishes collected were preserved except about a thousand which were large and offered no difficulty in identification and which were returned to the water. Notes made in the loose-leaf field book were removed daily, and later typed in triplicate, as is our regular procedure for field notes. The laboratory identifications were entered on the back of each page of the notes.

Within a day or two after the collections were made they were sorted and identified in the laboratory by the junior author and checked by the senior author. Mr. R. E. Richardson kindly checked many doubtful specimens and all of several doubtful and variable species. His help in this respect lends confidence in comparisons to be made with earlier collections which he identified. At the present time there is an unidentified residue of only 2 or 3 juvenile specimens.

The data were tabulated on large sheets of co-ordinate paper with half-inch squares. Across the top of each table were column headings for accession number, location, date, drainage area, depth, width, rate of flow, kind of bottom, submerged non-living cover (such as brush, logs, debris, *etc.*), aquatic vegetation, shade, turbidity, temperature, the factor used to reduce actual numbers of fishes taken to numbers per 100 square yards, and finally the names of the 74 species of county fishes. In these columns were tabulated the field data and numbers of each kind of fish in each collection. The collections were arranged in the order of their upstream-downstream occurrence in each stream. In the columns under the names of the fishes, the actual numbers taken and the calculated numbers per 100 square yards were entered. Horizontal and vertical totals were made and checked against each other. These tables were then used as the basis for all subsequent calculations and are preserved in the files of the Illinois Natural History Survey.

LIST OF SPECIES, WITH ANALYTICAL KEYS AND DATA ON DISTRIBUTION AND ABUNDANCE

The following list of the species of fishes taken in Champaign County is presented especially for the use of collectors in this area. For the sake of conformity the scientific names and the general arrangement are the same as in "The Fishes of Illinois" by Forbes and Richardson (1909) except that some of the common names have been changed to conform with local usage. An appendix (page 98) lists those Champaign County fishes which have revised names in Jordan's "Manual of the Vertebrate Animals of the Northeastern United States" 13th edition, 1929. Notes have been added in some cases for the convenience of the collector.

The data shown here are based on 132 quantitative collections made in 1928 which included 28,905 specimens, with the addition of three species (*Ictiobus bubalus*, *Hybopsis storerianus*, and *Etheostoma jessiae*) represented by single specimens taken in the earlier collections of the Illinois Natural History Survey, and two other readily recognized large species (*Anguilla chrysypa* and *Leptops olivaris*) taken by anglers in 1928.

The habitat numbers refer to an ecological classification of Champaign County streams and fishes which follows (pages 34-39). Several habitat numbers following the name of a species indicate that it occurs most frequently in the first habitat, and so on, with its least frequent occurrence in the last habitat. Maps are appended showing the local distribution of all species represented by ten or more specimens in the collections of 1928. An explanation of these maps is given on page 71.

The distribution of a species is described as "restricted" when it is absent from one or more of the stream systems in which its preferred habitat or habitats generally occur. In labelling certain species as "restricted," it has been necessary to take into account the number of specimens collected, since by random sampling it is within the realm of probability that a few specimens of a rare species may be taken in one stream system and not in others in which they may nevertheless occur. The word "restricted" used in connection with these species implies a spotty distribution and a high degree of isolation.

The following analytical keys to the Champaign County fishes have been adapted directly from the Forbes and Richardson keys, but a few minor modifications have been made, mostly within the family *Catostomidae*.

KEY TO THE FAMILIES OF CHAMPAIGN COUNTY FISHES

a Dorsal fin with no spines, or with only 1. Pelvic fin without spine.
  b Head naked.
    c Body scaled (scales small and obscure in the eel). Head without barbels or with not more than 2 or 4.
      d Gill membranes free from the isthmus, i. e., split far forward and meeting in an acute angle.
        e Lateral line present. (Moon-eye) .... **Hiodontidae**
        ee Lateral line wanting. Last rays of dorsal fin much elongated. (Gizzard-shad) .... **Dorosomidae**
      dd Gill membranes more or less broadly joined to the isthmus, not meeting in an acute angle.
        f Pelvic fins wanting. Body eel-shaped. (Eel) .... **Anguillidae**
        ff Pelvic fins present. Body not eel-shaped.
          g Pharyngeal teeth numerous and comb-like. Mouth fitted for sucking. Lips more or less thick and plicate or papillose. (Suckers) .... **Catostomidae**
          gg Pharyngeal teeth fewer than 8 on each side. Lips thin and never plicate or papillose. Dorsal fin of not more than 10 rays. (Minnows) .... **Cyprinidae**
    cc Body and head naked. Eight long barbels about the mouth. (Catfishes) .... **Siluridae**
  bb Head scaled. Body completely scaled.
    h Lateral line present. Front of head shaped like a duck's bill. (Pike) .... **Esocidae**
    hh Lateral line wanting. Mouth small and upturned. (Top-minnow) .... **Poecilidae**

aa Dorsal fin with more than one spine. Pelvic fin with a spine.
i Insertion of pelvic fins distinctly nearer the anal fin than the throat. First dorsal separated from the second and composed of 4 weak spines. (Silverside) .... **Atherinidae**
ii Insertion of pelvic fins distinctly nearer the throat than the first soft ray of the anal.
j Vent in front of pectorals. (Pirate-perch) .... **Aphredoderidae**
jj Vent normal.
k Anal spines 3 to 10. (Sunfishes) .... **Centrarchidae**
kk Anal spines one or two.
l Lateral line not extending onto the rays of the caudal fin. (Darters) .... **Percidae**
ll Lateral line extending onto the rays of the caudal fin. (Sheepshead) .... **Sciaenidae**

Family HIODONTIDAE—The Moon-eyes

Hiodon tergisus—Moon-eye; toothed herring.
1 coll. 1 spm. Habitat 9.

Family DOROSOMIDAE—The Gizzard-shad

Dorosoma cepedianum—Gizzard-shad; hickory shad.
2 colls. 17 spms. Habitat 9.

Family ANGUILLIDAE—The Eels

Anguilla chrysypa—Eel.
One reported taken in 1928 from the Embarrass River above Villa Grove.

Family CATOSTOMIDAE—The Suckers

Key to the Genera

a Dorsal fin elongate, with 25 to 40 developed rays.
b Distance from eye to lower posterior angle of preopercle about ¾ of that to upper corner of gill-cleft. Subopercle broadest at its middle, sub-semicircular. (Buffaloes) .... **Ictiobus**
bb Eye about equidistant between upper corner of gill-cleft and the lower posterior angle of preopercle. Subopercle broadest below its middle, subtriangular. (Carp-suckers) .... **Carpiodes**

aa Dorsal fin short, with 9 to 18 developed rays.
c Lateral line more or less incomplete or wholly wanting. Scales large and uniformly distributed, 30 to 50 in lateral line.
d Lateral line entirely wanting at all ages. Mouth subinferior, somewhat oblique. Young with wide, black lateral band breaking up into about six dark blotches in adults. (Chub-sucker) .... **Erimyzon**
dd Lateral line more or less developed in adults. Mouth inferior, horizontal. One dark squarish spot in center of each scale. (Spotted sucker) .... **Minytrema**
cc Lateral line complete and continuous.
e Scales small and crowded anteriorly. The number in the lateral line 55 to 110 (Except **C. nigricans** for which see below **ee**). (Suckers) .... **Catostomus**
ee Scales large and nearly equal all over the body, 40 to 55 in the lateral line.
f Air-bladder in two parts. Scales 48-55 in lateral line. (Hog sucker) .... **Catostomus (Hypentelium) nigricans**
ff Air-bladder in three parts. Scales larger, 40 to 50 in lateral line. (Red-horses) .... **Moxostoma**

Key to the Species of **Ictiobus**

a Mouth large, oblique. Upper lip about on level with lower margin of orbit. Angle of mandible with horizontal more than 40° .... **cyprinella**
aa Mouth smaller, little oblique. Level of upper lip about midway between chin and lower margin of orbit. Angle of mandible with horizontal slight, less than 20°
b Back scarcely elevated. Depth 3 to 3¼ in length. Body of adults subcircular at front of dorsal .... **urus**
bb Back elevated. Depth 2½ to 2¾ in length. Body strikingly compressed in adults .... **bubalus**

Ictiobus cyprinella—Red-mouth buffalo; big-mouth buffalo. 1 coll. 3 spms. Habitat 9.

Ictiobus urus—Mongrel buffalo; round buffalo. 1 coll. 1 spm. Habitat 8.

Ictiobus bubalus—Small-mouth buffalo; high-back buffalo. One taken in 1901 in Sangamon River. See Forbes and Richardson (1909).

Key to the Species of **Carpiodes**

a Distance from anterior nostril to end of snout less than diameter of eye. Snout blunt, squarish at tip. Profile of head flattish or slightly concave. Eye large, 3¾ to 4½ in head .... **difformis**
aa Distance from anterior nostril to end of snout greater than diameter of eye. Snout pointed at tip. Profile of head convex. Eye small, 4¾ to 5½ in head .... **velifer**

Carpiodes difformis—Blunt-nosed river carp.
4 colls. 30 spms. Habitat 9.

Carpiodes velifer—Quillback; silver carp.
9 colls. 13 spms. Habitats 8, 6, 9.

Erimyzon sucetta oblongus—Chub sucker; sweet sucker.
48 colls. 196 spms. Habitats 1, 5, 4, 6, 8, 9.

Minytrema melanops—Spotted sucker; striped sucker.
5 colls. 18 spms. Habitats 9, 8, 5.

Key to the Species of Catostomus

a Head transversely convex above. The orbital rim not elevated. Scales in lateral line, 60 or more, crowded and smaller anteriorly .... **commersonii**

aa Head broad, depressed, transversely concave between the orbits. Scales nearly equal all over the body, not crowded anteriorly, 48 to 55 in the lateral line .... **nigricans**

Catostomus commersonii—Black sucker; fine-scaled sucker.
65 colls. 644 spms. Habitats 8, 5, 6, 9, 4, 2, 7.

Catostomus nigricans—Hogsucker; stone-roller.
27 colls. 64 spms. Habitats 7, 8, 6, 5.

Key to the Species of Moxostoma

a Folds of lower lip more or less broken up into papillae.

b Head short, 4½ to 5½ in body. Caudal fin pink to bright red outward. Base of scales dark, giving a cross-hatched appearance. Developed dorsal rays 12 or 13 .... **breviceps**

bb Head longer, 3½ to 4½ in body. Mouth large. Developed dorsal rays 14 to 16. Back elevated. Color silvery .... **Anisurum**

aa Lips strongly plicate. Head 4 to 4½ in body. Caudal grayish olive to lemon. Outer margin of scales with dark stippling. Mouth large. Developed dorsal rays 12 to 14. Back scarcely elevated. Color bronze above lateral line .... **aureolum**

Moxostoma anisurum—White-nosed sucker.
One adult taken in September, 1929, from Sangamon River five miles above Mahomet.

Moxostoma aureolum—Common red-horse; white sucker.
22 colls. 114 spms. Habitats 8, 9, 7, 5, 6.

Moxostoma breviceps—Short-headed red-horse; red-tail.
6 colls. 11 spms. Habitats 8, 9, 6.

Family CYPRINIDAE—The Minnows and the Carp

KEY TO THE GENERA

a Dorsal fin elongate. Dorsal and anal fins each with a strong serrated spine. Teeth molar or submolar. (Carp) .... **Cyprinus**

aa Dorsal fin short. No spines in fins. Teeth not molar.

b Intestine more than twice length of body. Peritoneum usually black, brown, or dark gray. Generally mud-eaters.

c Intestine spirally wound around air-bladder .... **Campostoma**

cc Intestine not wound around air-bladder.

d Scales before dorsal 12 to 16 in number, not crowded .... **Hybognathus**

dd Scales before dorsal small and considerably crowded, 22 to 25 in number .... **Pimephales**

bb Intestine less than twice the length of body. Peritoneum usually pale. Generally carnivorous, or partly so.

e Maxillary without barbel.

f Mouth extremely small and upturned, the angle with vertical formed by its cleft less than 40° .... **Opsopoeodus**

ff Mouth horizontal or more or less oblique, the angle with vertical formed by its cleft usually more than 40°.

g Abdomen behind ventral fins with a sharp keel-like edge over which the scales do not pass. Body much compressed. Anal fin long, its rays 12 to 14 .... **Abramis**

gg Abdomen behind ventrals never sharply keeled, but rounded and fully scaled. Form various, elongate or fusiform, or more or less compressed.

h First (rudimentary) ray of dorsal club-like, covered with thick skin, and separated from second ray by a distinct membrane .... **Cliola**

hh First (rudimentary) ray of dorsal slender and bony and closely attached to second.

i Lips normal, nowhere conspicuously thickened. Mouth subterminal, more or less oblique.

j Lower portion of head rounded, not swollen, and without externally visible mucus channels .... **Notropis**

jj Lower portion of head with an appearance of being swollen. The suborbitals, interopercles, and dentaries with greatly distended mucus cavities, appearing externally as transverse vitreous streaks .... **Ericymba**

ii Lower lip with two lateral fleshy lobes, separated at the middle by the more or less horny and knob-like chin. Scales rather small, 40 to 60 in lateral line .... **Phenacobius**

ee Maxillary with a barbel at or near its extremity (sometimes quite small and difficult to make out, especially in preserved specimens).

k Barbel on upper side of maxillary and distinctly in front of its posterior tip. Mouth exceptionally large, maxillary 2.4 to 2.8 in head. Scales 50 to 60 .... **Semotilus**

kk Barbel terminal on the maxillary, situated in the axil formed at meeting of upper and lower lip-grooves. Maxillary more than 2.8 in head. Scales 35 to 45 in lateral line .... **Hybopsis**

Cyprinus carpio—Carp; European carp.
9 colls. 15 spms. Habitats 8, 9.

Campostoma anomalum—Dough-belly; stone roller.
64 colls. 1146 spms. Habitats 6, 7, 8, 2, 1, 4, 5.

Hybognathus nuchalis—Silvery minnow.
9 colls. 68 spms. Habitats 5, 8, 6, 7. Restricted to Kaskaskia River basin. Found among submerged vegetation, brush, and other cover.

Key to the Species of **Pimephales**

a Body short and stout, depth 3 to 4 in length. Lateral line more or less incomplete .... **promelas**

aa Body moderately elongate, depth 4 to 5 in length. Lateral line complete .... **notatus**

Pimephales promelas—Fathead minnow; black-head minnow.
19 colls. 103 spms. Habitats 8, 6, 4. Restricted to Sangamon River basin. Found in quieter water of permanently flowing streams.

Pimephales notatus—Blunt-nosed minnow.
110 colls. 6440 spms. Habitats 4, 5, 2, 6, 8, 1, 7, 9.

Opsopoeodus emiliae—Snub-nosed minnow.
1 coll. 2 spms. Habitat 5.

Abramis crysoleucas—Golden shiner; bream.
41 colls. 401 spms. Habitats 5, 8, 6, 3, 2, 4, 7. Almost invariably found among vegetation or other cover.

Cliola vigilax—Bullhead minnow.
4 colls. 24 spms. Habitat 8. Restricted to the Sangamon River and the East Branch of the Salt Fork. Found in shallow, quiet water with mud bottom and no vegetation, cover or shade.

Key to the Species of **Notropis**

a Anal rays typically 7 or 8, occasionally 9 in two compressed forms (see **bb** below), in which however, scales before dorsal are not over 17, and no black spot is present at base of first dorsal rays.

b Eye moderate, 2⅓ to 2⅔ in head, always less than 4. Body not usually much compressed, the body gently and broadly rounded in front of dorsal fin. Scales not closely imbricated.

c Eye 3 or more in head. Small, usually less than 2½ inches.

d Scales before dorsal large, 12 to 15 in number.
e A black stripe along sides through eye to end of snout. Chin white. Mouth small, nearly horizontal .... **cayuga**
ee A dark vertebral streak, and a plumbeous lateral band more or less distinct posteriorly. Mouth more or less oblique. Lateral line distinctly decurved anteriorly .... **blennius**
dd Scales before dorsal smaller, 17 to 19 in number. Mouth inferior. Lips rather thick .... **gilberti**
cc Eye very large, 2⅓ to 2¾ in head. Dark lateral stripe not developed anteriorly. Some dusky color on chin at tip. Length 3 inches .... **illecebrosus**
bb Eye small, 4 to 5 in head in adults. Body more or less distinctly compressed, the back sharply rounded in front of dorsal fin. Scales closely imbricated. Adults with depth 3½ to 4 in length. A more or less distinct black blotch on last membranes of dorsal .... **whipplii**
aa Anal rays 9, 10, 11, or 12.
f Dorsal in front of or over ventrals. Exposed portions of scales of flanks notably deeper than long. A broad dark vertebral streak. Aanal rays 9 to 10, usually 10 .... **cornutus**
ff Dorsal fin behind ventrals. Scales roundish, the exposed portions not notably deeper than long.
g Scales loosely imbricated, those before dorsal in 15 to 17 series. No black spot at base of dorsal.
h A dark vertebral streak. Anal rays 9 or 10 .... **pilsbryi**
hh Vertebral streak very narrow and usually faint. Snout blunt. Maxillary equal to eye .... **atherinoides**
gg Scales closely imbricated, about 30 series in front of dorsal. A black spot usually evident at front of base of dorsal. Anal rays 10 to 12, usually 11 .... **umbratilis**

Notropis cayuga atrocaudalis—Cayuga minnow.
1 coll. 1 spm. Habitat 8.

Notropis blennius—Straw-colored minnow.
44 colls. 1573 spms. Habitats 8, 6, 7, 5, 1.

Notropis gilberti—Gilbert's minnow.
5 colls. 53 spms. Habitats 6, 8, 5. Restricted to Sangamon River basin. Found in shallow, quiet water over sandy bottom.

Notropis illecebrosus—Big-eyed minnow.
2 colls. 8 spms. Habitat 7. Restricted to Middle Fork River. Found below rapids among stalks of the water willow, *Dianthera americana*.

Notropis whipplii—Steel-colored minnow; silverfin.
53 colls. 1994 spms. Habitats 8, 7, 6, 4, 2, 5. Found on or near riffles and briskly moving water. Strong swimmer.

Notropis cornutus—Shiner; horned shiner.
54 colls. 2618 spms. Habitats 5, 6, 7, 8, 4, 2, 9. Found abundantly in Sangamon, Middle Fork, and Kaskaskia River basins. A few specimens taken in Salt Fork Basin. Very closely associated with *Hybopsis kentuckiensis.*

Notropis pilsbryi—Pilsbry's minnow.
6 colls. 17 spms. Habitats 5, 6.

Notropis atherinoides var.—Shiner.
3 colls. 21 spms. Habitat 7. Restricted to Middle Fork River.

Notropis umbratilis atripes—Blackfin minnow.
69 colls. 1108 spms. Habitats 6, 5, 8, 7, in about equal frequency. Shows preference for vegetation or other cover.

Ericymba buccata—Silver-mouthed minnow.
79 colls. 3519 spms. Habitats 2, 6, 5, 8, 7, 4. Found most often and in largest numbers over sand bottom.

Phenacobius mirabilis—Sucker-mouthed minnow.
24 colls. 102 spms. Habitats 8, 6, 7, 5.

Semotilus atromaculatus—Horned dace; creek chub.
101 colls. 2873 spms. Habitats 4, 2, 1, 6, 5, 8, 7, 3.

Key to the Species of **Hybopsis**

a Upper jaw decidedly inferior, lying below the projecting snout. Preorbital much narrower than eye. No nuptial tubercules. Upper jaw reaching eye.
  b Size small, 2 to 3 inches when adult. Dorsal fin inserted over origin of ventrals, usually a little nearer caudal base than tip of snout. Dark lateral stripe. Color silvery. Upper jaw 3.6 to 4.6 in head .... **amblops**
bb Size large, 4 to 10 inches when adult. Dorsal fin inserted distinctly in advance of ventrals, decidedly nearer snout than caudal base. Color silvery without a dark lateral stripe. Upper jaw 3.2 to 3.7 in head .... **storerianus**
aa Upper jaw almost terminal. Snout rather conical. Preorbital much wider than eye. Nuptial tubercles very strong. Large fishes with the aspect of Semotilus........ **kentuckiensis**

Hybopsis amblops—Big-eyed chub; silver chub.
8 colls. 40 spms. Habitats 8, 6. Restricted to Middle Fork, Salt Fork, and Embarrass rivers.

Hybopsis storerianus—Storer's chub.
One taken in 1899 in Middle Fork River. See Forbes and Richardson (1909).

Hybopsis kentuckiensis—Horny head; Kentucky chub.
46 colls. 1221 spms. Habitats 5, 6, 7, 8, 4, 9. Found closely associated with *Notropis cornutus* in Sangamon, Middle Fork, and Kaskaskia River basins.

Family SILURIDAE—The Catfishes

KEY TO THE GENERA

a Adipose fin with its posterior margin free.
  b Premaxillary band of teeth without lateral backward extensions. Anal rays 17 to 35, including rudiments.
    c Bony bridge from occiput to dorsal fin complete. Tail deeply forked .... **Ictalurus**
    cc Bony bridge from occiput to dorsal fin broken. Caudal fin typically rounded, truncate or slightly emarginate .... **Ameiurus**
  bb Premaxillary band of teeth with a backward extension on each side. Anal rays 12 to 15 including rudiments .... **Leptops**
aa Adipose fin adnate to the back, continuous with the caudal and separated from it only by a notch.
  d Premaxillary band of teeth with lateral backward extensions, as in **Leptops**. Skin thick tough, and villose, not translucent .... **Noturus**
  dd Premaxillary band of teeth truncate at the ends, as in **Ameiurus**. Skin thinner than in **d**, smooth or very finely villose, sometimes translucent .... **Schilbeodes**

Ictalurus punctatus—Channel cat; fiddler.
8 colls. 10 spms. Habitats 8, 9.

Key to the Species of Ameiurus

a Anal rays 24 to 27, including rudiments, usually 25 or 26. Caudal fin rounded posteriorly. Margin of anal fin a straight line .... **natalis**
aa Anal rays 17 to 20, usually 18 or 19, including rudiments. Caudal fin always evidently emarginate. Margin of anal fin a curve .... **melas**

Ameiurus natalis—Yellow bullhead.
15 colls. 28 spms. Habitats 5, 6, 8.

Ameiurus melas—Black bullhead; horned pout.
13 colls. 1704 spms. Habitats 3, 5, 8, 9. Schools of young found in habitats 3, 5.

Leptops olivaris—Mud-cat; yellow cat; goujon.
One 24 pound spm. taken August 1928 in Sangamon River by Mr. Homer Bales.

Noturus flavus—Stonecat.
5 colls. 12 spms. Habitat 7. Found under rocks on riffles.

Key to the Species of **Schilbeodes**

a Anterior and posterior edges of pectoral spine entire, or the anterior edge very slightly roughened near tip. Jaws equal. Adipose fin continuous with caudal, the notch being absent or faint, never acute. Color purplish olive to dark brownish, without noticeable specking. Three dark streaks on sides .... **gyrinus**

aa Pectoral spine with distinct posterior serrae, which are recurved and in length more than 1/3 the diameter of spine. Notch between adipose and caudal fins always more or less acute.

b Pectoral spine short, 3 in head, the posterior serrae not ½ diameter of spine. Notch between caudal and adipose fins usually shallow. Color light brown, sometimes faintly mottled. A large squarish spot of lighter color on back before dorsal and a smaller cresentic one behind it .... **exilis**

bb Pectoral spine longer, less than 2 in head, its posterior serrae strong and in length nearly equaling diameter of spine. Notch between adipose and caudal fins deep and acute. Color grayish with black specks and larger blotches. Four saddle-like blotches on back, the last but one extending upon adipose fin to its edge .... **miurus**

Schilbeodes gyrinus—Tadpole cat.
7 colls. 14 spms. Habitats 8, 6. Restricted to Salt Fork River basin.

Schilbeodes exilis—Slender stonecat.
3 colls. 3 spms. Habitats 8, 7.

Schilbeodes miurus—Brindled stonecat.
1 coll. 44 spms. Habitat 8. Restricted to Salt Fork River basin.

Family ESOCIDAE—The Pikes

Esox vermiculatus—Grass pike; little pickerel.
26 colls. 63 spms. Habitats 8, 5, 6. Found among submerged vegetation or other cover, and in the shade of overhanging bushes.

Family POECILIIDAE—The Killifishes

Fundulus notatus—Top minnow.
44 colls. 151 spms. Habitats 8, 5, 6. Found most often near aquatic vegetation. Swims commonly with back touching the surface film.

Family ATHERINIDAE—The Silversides

Labidesthes sicculus—Brook silverside.
3 colls. 27 spms. Habitat 8. Restricted to the Salt Fork River basin.

Family APHREDODERIDAE—The Pirate-perch

Aphredoderus sayanus—Pirate-perch.
12 colls. 167 spms. Habitats 5, 8. Restricted to Sangamon, Embarrass, and Kaskaskia River basins. Found among living vegetation or other cover.

Family CENTRARCHIDAE—The Sunfishes

Key to the Genera

a Dorsal fin little longer than anal, if any, its length 1 to 1.4 times length of anal base. Anal spines 5 to 8 in number.
  b Dorsal spines 5 to 8 (occasionally 9 or even 10) (Crappies) .... **Pomoxis**
  bb Dorsal spines 11 to 13. Anal spines 6, rays 10 or 11. (Rock bass) .... **Ambloplites**
aa Dorsal more than twice length of anal. Anal spines 3.
  c Body comparatively short and deep, depth in adults as a rule more than 2/5 of length. Dorsal fin not deeply emarginate, the shortest spine behind middle of fin more than 2/3 height of longest. Operculum entire behind, not emarginate, more or less prolonged in a bony process or flap with a rounded posterior margin.
    d Tongue and pterygoids with teeth. Maxillary reaching past pupil (Warmouth bass) .... **Chaenobryttus**
    dd Tongue and pterygoids toothless. Maxillary in most species short of middle of orbit (to middle in **L. cyanellus).** Pectorals never reaching beyond vertical from base of anal. Opercular flap without red, or if red is present, with the color forming a border and not a roundish spot. (Sunfishes, and the bluegill) .... **Lepomis**

cc Body comparatively elongate, depth about 1/3 length. Dorsal fin deeply emarginate, the shortest spine behind middle of fin from 1/3 to ½ height of longest. Operculum ending in two flat points. (Black basses) .... **Micropterus**

Key to the Species of **Pomoxis**

a Dorsal spines typically 6, rarely 5 or 7. Color light, the dark markings tending to form vertical bands .... **annularis**

aa Dorsal spines typically 7 or 8, rarely 6, 9, or 10. Color dark, spotted, the dark markings not forming vertical bands .... **sparoides**

Pomoxis annularis—White crappie.
2 colls. 2 spms. Habitat 8.

Pomoxis sparoides—Black crappie.
3 colls. 7 spms. Habitats 9, 8.

Ambloplites rupestris—Rock bass; goggle-eye.
1 coll. 1 spm. Habitat 8.

Chaenobryttus gulosus—Warmouth bass.
2 or 3 spms. collected in recent years near the outlet of Crystal Lake from which they had probably escaped.

Key to the Species of **Lepomis**

a Black opercular spot borne by the stiff bony upper posterior angle of the operculum, which is plainly distinguished from a flexible (fleshy or membranous) border of different (usually lighter) color.

b Mouth large and cheek not very deep, the maxillary 1/5 to ¼ longer than the distance from the lower margin of the orbit to the lower posterior corner of the preopercle. In life with blue spots and vertical bars of dusky. Margin of ear-flap coppery to purplish. Cheeks with wavy blue lines .... **cyanellus**

bb Mouth smaller and cheek deeper, maxillary about equal to or less than distance from lower margin of orbit to the lower posterior corner of preopercle. Many scales of sides with squarish light-colored areas (bronze or purplish in life), these forming more or less distinct longitudinal rows. Rest of body dusky olive .... **miniatus**

aa Portion of opercular flap bearing black spot very thin and flexible.

c Bony portion of operculum terminating in front of the middle of the black opercular spot, which is confined chiefly to the broad pale (pinkish in life) membranous (not osseus) border. In life olive with orange spots. Cheeks and opercles with wavy broken lines of rusty orange. No black blotch at base of last dorsal rays .... **humilis** cc Bony portion of operculum continued backward as a thin and flexible osseo-membraneous flap, which is all or nearly all black, the longitudinal bone-striae being visible through its ensheathing epidermis.

d Gill-rakers short and weak, their length not over 1/6 eye. No black spot at base of last dorsal rays. Olive with blue and orange spots and wavy vertical streaks of emerald. Cheeks with wavy lines of emerald........**megalotis**

dd Gill-rakers rather long and slender, their length nearly 1/3 of eye. A black blotch at base of last dorsal rays. Life color olive, with purplish luster........**pallidus**

Lepomis cyanellus—Green sunfish.
38 colls. 121 spms. Habitats 3, 5, 6, 2, 8, 7, 4. Usually found among vegetation or other cover.

Lepomis Miniatus—Garman's sunfish.
1 spm. collected in 1928 near the outlet of Crystal Lake, from which it had probably escaped.

Lepomis megalotis—Long-eared sunfish.
39 colls. 154 spms. Habitats 8, 5, 6, 4, 9. About 20 adults observed building nests and spawning in the Little Vermilion River at the Champaign-Vermilion County line on August 2, 1928. The stream at this point is a dredge ditch with 3 to 10 inches of water and a muddy gravel bottom.

Lepomis humilis—Orange-spotted sunfish.
13 colls. 35 spms. Habitats 8, 2, 5, 6. Restricted to Sangamon, Salt Fork, and Middle Fork River basins.

Lepomis pallidus—Bluegill.
1 spm. taken in 1928 near the outlet of Crystal Lake, from which it had probably escaped.

Key to the Species of Micropterus

a Mouth moderate, the maxillary never extending beyond eye, usually a little short of back of orbit. Scales on cheeks in about 17 rows. Young more or less barred or spotted, never with a black lateral band........**dolomieu**

aa Mouth very large, the maxillary in the adult extending past back of orbit. Scales on cheek large, in about 10 rows. Young with a blackish lateral band........**salmoides**

Micropterus dolomieu—Small-mouthed black bass.
16 colls. 44 spms. Habitats 8, 7, 6, 9. Usually found near submerged brush or logs. Good swimmer. Commonly jumps clear of water when disturbed.

Micropterus salmoides—Large-mouthed black bass.
3 colls. 4 spms. Habitats 8, 6. It has been noticed that where this species is found in creeks there is usually a good growth of the water willow, *Dianthera americana*. Not so active as *M. dolomieu*.

Family PERCIDAE—The Darters

KEY TO THE GENERA

a Pre-maxillaries not protractile, free only at the sides, connected in front with the skin of the forehead, from which they are not separated by a cross groove.

b Cranium not compressed or much elevated back of eyes, its elevation not more than 1/3 of its breadth. Body as a rule more or less slender and little compressed, subcylindrical or fusiform. Depth in length as a rule 6 or more. Spring males ordinarily without red or other gaudy coloration.

c Cranium broad between the eyes, the interorbital space 4 to 4.7 in head. Snout pig-like. Darters of large size, reaching a length of 6 inches. (Log perch)........**Percina**

cc Interorbital space narrower, 5.5 to 9 in head. Small fishes, ordinarily not over 4 inches in length. Body moderately slender, the depth as a rule about 6 in length (sometimes 7)........**Hadropterus**

bb Cranium more or less compressed and elevated back of eyes, Ո- shaped, its elevation as a rule noticeably more than 1/3 (to less than ½) its breadth (except in **E. flabellare** which has a low spinous dorsal and spring males without gaudy coloration). Fishes with usually more or less compressed and comparatively shortened bodies, the depth in length as a rule less than 6. Spring males usually with brilliant red, blue, or green coloration.

d Lateral line not noticeably flexed upward anteriorly........**Etheostoma**

dd Lateral line conspicuously flexed upward anteriorly, its direction parallel with line of back (least distance between lateral line and middle of back in **B. fusiformis** about ¼ depth of body at same point)........**Boleichthys**

aa Premaxillaries protractile, i. e., a groove separating them from the skin of the forehead.

e Groove separating premaxillaries from forehead inferior, not visible except from below. Maxillary adnate to the preorbital for most of its length, nearly immovable. Anal spines 2........**Diplesion** ee Groove separating premaxillaries from forehead superior, easily visible from in front and above. Maxillary separated by groove from preorbital for its entire length. Anal spine single.

f Anal fin much smaller than soft dorsal. Body moderately slender, depth not over 7 in length. Not hyaline in life .... **Boleosoma**

ff Anal fin almost as large as soft dorsal. Body extremely slender, depth in length 8 to 10. Body hyaline in life.... **Ammocrypta**

Percina caprodes—Log perch.
2 colls. 4 spms. Habitat 7.

Key to the Species of **Hadropterus**

a Gill membranes not broadly united at the isthmus, distance from tip of snout to angle formed by their union scarcely exceeding that to back of orbit. Color pattern longitudinal, the sides marked with a median row of blotches or a moniliform band, above which are longitudinally disposed marblings. Cheeks scaled .... **aspro**

aa Gill membranes united at isthmus in a broad curve, least distance from muzzle to free margin of gill membranes 1.2 to 1.5 times that from muzzle to back of orbit. Head very slender and snout long and pointed. Lateral blotches small and as a rule faint. A very small central caudal spot .... **phoxocephalus**

Hadropterus aspro—Black-sided darter.
24 colls. 45 spms. Habitats 8, 5, 6, 7. Often found among aquatic vegetation or other cover.

Hadropterus phoxocephalus—Sharp-nosed darter.
8 colls. 12 spms. Habitats 8, 7, 6.

Diplesion blennioides—Green-sided darter.
10 colls. 149 spms. Habitats 7, 8, 6. Restricted to Middle Fork, Salt Fork, and Embarrass River basins. Found on swiftest riffles.

Key to the Species of **Boleosoma**

a Lateral line complete or nearly so. Pyloric caeca 6. Cheeks and breast typically naked, sometimes more or less scaly........ **nigrum**

aa Lateral line absent on posterior half of body. Pyloric caeca 3. Cheeks and opercles, and usually breast, closely scaled.... **camurum**

Boleosoma nigrum—Johnny darter.
82 colls. 993 spms. Habitats 8, 5, 6, 2, 4, 7.

Bolcosoma camurum—Snub-nosed darter.
1 coll. 1 spm. Habitat 5.

Ammocrypta pellucida—Sand darter.
2 colls. 19 spms. Habitat 8. Restricted to Middle Fork River. Found buried in sand above riffles.

Key to the Species of **Etheostoma**

a Lateral line usually complete, occasionally 2 to 6 pores lacking. Gill membranes joining broadly across the isthmus .... **zonale**

aa Lateral line always more or less incomplete, the number of pores lacking usually 10 to 30, rarely as low as 5.

b Spinous dorsal fin not exceptionally low, its height as a rule 75 to 90 per cent of height of soft dorsal. No enlarged dark humeral scale.

c Cheeks and opercles scaled. Brown bars on sides .... **jessiae**

cc Cheeks naked. Opercles scaled. Spring males with alternating red and blue bars .... **coeruleum**

bb Spinous dorsal fin as a rule less than 60 per cent height of soft dorsal. An enlarged dark humeral scale more or less conspicuous. Gill membranes broadly connected. Dorsal spines each ending in a fleshy knob in the male .... **flabellare**

Etheostoma zonale—Banded darter.
8 colls. 85 spms. Habitats 7, 8. Restricted to the Sangamon River.

Etheostoma jessiae—
One spm. taken in 1901 in Sangamon River. See Forbes and Richardson (1909).

Etheostoma coeruleum—Rainbow darter.
32 colls. 497 spms. Habitats 6, 7, 8, 5, 4. Not found in the Kaskaskia Basin.

Etheostoma flabellare—Fan-tailed darter.
14 colls. 34 spms. Habitats 7, 8, 6. Restricted to Sangamon, Embarrass, Middle Fork, and Salt Fork River basins. Found under and around rocks on riffles.

Bolcichthys fusiformis—
1 coll. 1 spm. Habitat 6.

Family SCIAENIDAE—The Drums

Aplodinotus grunniens—Sheepshead; white perch; drum.
3 colls. 10 spms. Habitats 9, 8.

TYPE HABITATS

Habitat numbers given in the preceding species list refer to the following classification of type habitats as found in the streams of Champaign County. In the selection of these type habitats we have chosen those stream situations which occur repeatedly and have made them correspond, in as far as possible, with what appear to be natural subdivisions in the distribution of the fishes. It is, of course, to be understood that a stream is a continuum and does not break abruptly from one situation into another. There are marked differences in the details of the environment in these type habitats and corresponding differences in the detailed distribution of the fishes.

Type Habitat 1

Vernal Rivulets

Commonly draining ½ to 2 square miles. Flowing for a few weeks in spring and for shorter periods following heavy rains. Completely dry throughout most of the year. One to six inches deep. Six inches to four feet wide. They are often so small that they can be dammed by one's hand. The substrate is of exposed subsoil with an accumulation of loam in the depressions. Occasional short stretches of sand bottom may occur depending on the kind of soil being eroded. There are no characteristic bottom muds nor gravelly or rocky riffles. There is usually considerable dead vegetation in the form of drifts of leaves, dead weeds, sticks, cornstalks, grass, *etc.* No living vegetation except for occasional pieces of sod. The aquatic animal food present for fishes is restricted almost entirely to water isopods. A considerable number of terrestrial animals are washed in and also serve as food. The typical species of this habitat are as follows:

Erimyzon sucetta oblongus, young
Pimephales notatus, young
Semotilus atromaculatus, young
Campostoma anomalum, young

The above fishes are known to feed extensively on mud and organic debris. The young of a few other species may occur in small numbers.

Type Habitat 2

Kettle Holes at Mouths of Tile Drains

Commonly draining from 1 to 7 square miles. There is a flow throughout the year but it is often reduced to a trickle. Usually 10 to 25 feet wide and 1½ to 4 feet deep. Water temperature not exceeding 65°F. in summer and seldom freezing in winter. Very clear. No aquatic vegetation except filamentous algae. Bottom usually of clay, rock, gravel, and sand. No characteristic dark-colored

5. On the afternoon of July 28, 1929, two of these kettle holes were visited and temperatures taken. On that afternoon the air temperature in the shade varied around 95°F. The temperature of one was 63.3°F. and the other 62.6°F. The water temperature as it came from the two tiles was 62.8°F. and 61.3°F., respectively.

bottom muds. No cover except a little overhanging grass and some submerged trash, dead leaves, and weeds. Very little available aquatic animal food apparent. Grasshoppers and other terrestrial insects fall into the water and probably fill an important place in the dietary of the fishes. No shade. The typical fishes in these situations are as follows:

Ericymba buccata, adults
Semotilus atromaculatus, adults and young
Pimephales notatus, adults
Catostomus commersonii, young
Campostoma anomalum, adults and young

When the tile outlet is sufficiently low some of these fishes, notably *Ericymba* and *Semotilus*, will ascend the tile for considerable distances where they may feed on subterranean amphipods and isopods.

Type Habitat 3

Oxbow Ponds along Small Streams

Commonly draining ½ to 1 square mile. Flowing during wet weather. Flooded by adjacent stream during freshets. Usually wide, shallow ponds with a bottom of deep, soft, black, mucky mud. Much dead and decaying vegetation. Usually with emergent coarse aquatic vegetation of *Saggittaria*, smartweeds, bullrushes, docks, *etc.* In summer with heavy growths of blanket algae and duck weeds. Seldom shaded; water extremely warm in summer weather. Freezes almost to bottom in winter. Numbers of frog tadpoles of several species can often be found. Small crayfishes numerous. An abundance of a large variety of aquatic animal food. The typical fishes are as follows:

Ameiurus melas, adults and young
Lepomis cyanellus, adults and young
Esox vermiculatus, adults and young
Abramis crysoleucas, adults and young

Occasional young specimens of other species are also found. The conditions of these small oxbow ponds are sometimes approximated in the upper ends of dredge ditches and there the above fishes are also found.

Type Habitat 4

Permanent Headwater Streams

Commonly draining 2 to 10 square miles. Reduced during drouths to mere trickles running from one shallow depression to another. One inch to one foot deep and six inches to six feet wide. Substrate usually of exposed subsoil but occasional gravelly riffles and beginnings of characteristic bottom muds are seen. Shaded by a luxuriant growth of cattails, grasses, weeds, willows, and other shrubs and small trees. Water cool. No submerged coarse aquatic vegetation. May have some duck weed and filamentous algae in summer. Available aquatic animal food for fishes not abundant. Numbers of dragon fly and damsel fly nymphs and water striders and other bugs. Much food probably falls from the overhanging vegetation. The typical fishes in this situation are:

Semotilus atromaculatus, adults and young
Pimephales notatus, adults and young

Sometimes the fish population consists entirely of *Semotilus.* At other times a few specimens of other species may also be found.

Type Habitat 5

Stretches of Shallow, Sluggish Water

Found in both dredged and undredged streams with a drainage area of 5 to 40 square miles. Reduced to long quiet pools in dry weather. Three to twenty feet wide and ½ to 2½ feet deep. In summer the water is relatively warm and is turbid. In winter covered with heavy ice. The bottom is characteristically of dark mud with an admixture of small amounts of sand, gravel, rock, and sticks. The banks are usually steep and drop off quickly to an almost uniform depth. There is characteristically a growth of a variety of submerged and emergent coarse aquatic vegetation, and the channel often is literally choked with beds of water smartweed. Small amounts of shade are furnished by overhanging grass and weeds and a few willows. A variety of aquatic animal foods is present in fair abundance, with Hexagenia nymphs near first place. Crayfishes are common and often are extremely abundant. The typical fishes in this habitat are:

Catostomus commersonii, adults and few young
Notropis cornutus, adults and young
Hybopsis kentuckiensis, adults and young
Semotilus atromaculatus, adults and young
Abramis crysoleucas, adults and young
Erimyzon sucetta oblongus, adults and young
Esox vermiculatus, adults and young
Fundulus notatus, adults and young
Pimephales notatus, adults and young
Aphredoderus sayanus, adults and young
Lepomis megalotis, adults and young
Lepomis cyanellus, adults and young
Boleosoma nigrum, adults and young

Small numbers of other fishes are regularly taken. This is one of the more important fish habitats inasmuch as it occurs commonly in Champaign County and supports a large population of a variety of fishes.

Type Habitat 6

Gravelly and Sandy Riffles and Stretches

Drainage area 8 to 40 square miles. One to 12 feet wide and 1 to 8 inches deep. May be a few feet long or several hundred yards long. Either in dredged ditches or in natural streams that loop and meander. Small flow in dry weather.

Bottom of gravel or sand, more commonly of both. Often with pebbles ranging up to two inches or more in diameter. Mud along banks and in shallow depressions. Exposed roots of willow, brush, and overhanging sod and grass and shore vegetation. Sometimes there are small amounts of coarse aquatic vegetation. Moderate amounts of aquatic animal food. The typical fishes are:

Catostomus nigricans, young and few adults
Campostoma anomalum, adults and young
Semotilus atromaculatus, adults and young
Notropis whipplii, adults and young
Catostomus commersonii, young
Notropis cornutus, adults and young
Hybopsis kentuckiensis, adults and young
Pimephales notatus, adults and young
Ericymba buccata, adults and young
Notropis umbratilis atripes, adults and young
Boleosoma nigrum, adults and young
Etheostoma coeruleum, adults and young
Etheostoma flabellare, adults and young
Moxostoma aureolum, young
Carpiodes velifer, young

Smaller numbers of other fishes are regularly taken.

Type Habitat 7

Rocky Rapids and Riffles

Draining 40 to 400 square miles. Depth 2 to 15 inches. Width 5 to 40 feet, very swift except during very low stages of water. Commonly 10 to 100 yards long. Bottom of rocks from the size of eggs up to boulders and loose trap rock interspersed with solidly packed gravel and sand. Occasional logs and brush in water along edges. Rocks overgrown with spreading growths of algae, diatoms, bryozoa, etc., and often serving as anchors for long streamers of *Cladophora*. An abundance of animal food, consisting principally of small mollusks and immature stages of may flies and caddis flies. This situation occurs in both dredged and natural streams. There are usually trees and shrubs on the banks, which partially shade the water. The typical species of this habitat are:

Catostomus nigricans, adults
Phenacobius mirabilis, adults and young
Ictalurus punctatus, young
Etheostoma flabellare, adults and young
Etheostoma zonale, adults and young
Hybopsis kentuckiensis, adults and young
Notropis cornutus, adults and young
Notropis whipplii, adults and young
Hybopsis amblops, adults and young
Percina caprodes, adults
Diplesion blennioides, adults and young
Noturus flavus, adults and young

Small numbers of other fishes taken under certain conditions. The fishes of this situation are mostly adapted to hiding behind and under rocks or other objects that break the full force of the current. These species are seldom seen swimming except for sudden spurts of speed from one stopping place to another. They hold their position rather by avoiding the full force of the current and clinging than by excellence of swimming.

Type Habitat 8

Moderately Deep, Smoothly Flowing Stretches

Draining 40 to 400 square miles. Depth 1 to 4 feet. Width 20 to 50 feet. Current sluggish during periods of low water. Bottom of sand and gravel with mud along the banks. No coarse aquatic vegetation. Usually with no overhanging grass or weeds. Commonly shaded by trees on the banks. Roots of trees often exposed and offer hiding places for sunfishes. Numerous drifts of brush and logs and stumps commonly accumulated in places where a large tree has fallen in. The banks usually drop off steeply to a uniform depth. Moderate amounts of a variety of animal foods. Mussels of several species numerous. The typical fishes of this situation are:

Moxostoma aureolum, adults
Moxostoma breviceps, adults
Carpiodes velifer, adults
Catostomus commersonii, adults
Catostomus nigricans, adults
Micropterus dolomieu, adults and young
Pomoxis annularis, adults and young
Pimephales notatus, adults
Notropis blennius, adults
Notropis whipplii, adults
Notropis cornutus, adults
Hybopsis kentuckiensis, adults
Ictalurus punctatus, adults and young
Lepomis cyanellus, adults and young
Lepomis megalotis, adults and young
Lepomis humilis, adults and young

Other fishes are also taken in smaller numbers.

Type Habitat 9

Long, Deep Pools

Draining 100 to 400 square miles. Width 40 to 75 feet. Depth 3 to 8 feet. There is less fluctuation of the physical environment of this habitat than any other small stream situation. Mud bottom with more or less gravel and water-logged sticks. Mud banks. Usually with partly submerged logs and brush along banks. Partly shaded by trees. Sometimes turbid. No aquatic vegetation except for water bloom and duck weed in late summer. Usually with aquatic animal food in the form of small mollusks, Tubificid worms, and chironomid larvae. The typical fishes are:

Aplodinotus grunniens, adults and young
Dorosoma cepedianum, adults and young
Carpiodes difformis, adults
Moxostoma aureolum, adults
Moxostoma breviceps, adults
Micropterus salmoides, adults and young
Ictiobus cyprinella, adults and young
Cyprinus carpio, adults and young
Catostomus commersonii, adults
Pomoxis sparoides, adults and young
Ictalurus punctatus, adults
Ameiurus melas, adults

Other large fishes are taken in smaller numbers. Scanty numbers of smaller kinds of fishes are taken regularly. Snapping turtles are found here most often. Painted turtles numerous. This situation is the winter quarters of most of the larger fishes.

Abundance and Number of Kinds

In the present quantitative collections a total of 28,905 fishes were taken from a total water area of 9,535 square yards or 1.97 acres—about 15,000 per acre, or 3 per square yard. The total weight of these fishes was estimated at 300 pounds, or about 150 pounds per acre for the county streams as a whole. This average weight of fish flesh per acre has no obvious relation to the annual yield of food fishes or to the annual increment.

On the basis of some fragmentary data on the rate of growth of Champaign County fishes and on a general knowledge of the size and relative numbers of the different age groups of the principal species, one may venture a guess that the annual increment, or turnover, of fish flesh is something less than one-half of the total 150 pounds per acre.

In this area food and game fishes may be taken only by hook-and-line, and minnows may be taken for bait with small minnow seines. In general, the fishes in this county are too small to be attractive to many anglers, and the weight of the fishes taken from the water by man is surely a very small percentage of the annual increment. In these streams we probably have a close approximation to an equilibrium, or a balance wherein the annual increase in fish flesh equals the annual decrease, and that without undue influence or control by man. Most fishes in these streams die of "natural" causes—they may be eaten at any period of their life by any one of a variety of predators such as carnivorous insects, crayfishes, necturi, turtles, water and shore birds, or the mink. They may be injured or stunted or destroyed by any one of a long and imposing list of specific fish diseases and parasites. Under certain conditions their food may be exhausted or seriously depleted. Their ambient medium may dry up or get too hot or freeze solid or be deficient or unsuitable in a number of other ways. Compared with these vicissitudes an occasional worm on a hook is a minor hazard.

Some recent work of Dr. H. J. Van Cleave and Mr. H. C. Markus on the life history of the blunt-nosed minnow, *Pimephales notatus,* in this area suggests that females and males of this species do not exceed 2 and 3 years in age, respectively. The implication is that they die following their first spawning period. (*Amer. Nat.* 63: 530-539, 1929.)

Of those species which occur both in these small streams and in the large rivers of Illinois the average size is much less in the small streams. Such size differences among the suckers and red-horses are obviously due to migration, since these fishes ascend the small streams and spawn and then descend. Size differences may also be due to slower growth or greater relative elimination in the small streams. In any case it seems probable that the annual "turn-over" in fish flesh is greater in these small streams than in the larger rivers.

Eight of the thirteen families of fishes in Champaign County are represented by single species. The remaining five families are represented by species as follows: Catfishes 8, Suckers 12, Sunfishes 11, Darters 12, Minnows 23. In point of weight the sucker family (*Catostomidae*) takes first place, furnishing somewhat more than half of the total weight of fishes taken. About three-fourths of this total weight of the sucker family was contributed by the common, or black, sucker, *Catostomus commersonii,* which averaged 3 ounces in weight. In point of numbers of individuals the minnow family *(Cyprinidae)* excels, contributing 23,347 of the total of 28,905 specimens taken. Of the 23 species of minnows taken, the following 9 species furnished 22,492 specimens.

Campostoma anomalum
Pimephales notatus
Semotilus atromaculatus
Notropis blennius
Notropis whipplii
Notropis cornutus
Notropis umbratilis atripes
Ericymba buccata
Hybopsis kentuckiensis

Most of these are headwater species, generalized, both physiologically and morphologically, and will be discussed more fully later.

To illustrate the wide range of abundance, one species is represented by 6,440 specimens in one season's collecting, while 12 others are represented by single specimens each. Such differences in abundance of the various species as we find in this study are not satisfactorily explained by one or a few factors, and it seems that an adequate explanation will involve not only a complete and intimate knowledge of all the variable factors of the physical environment but—what is more difficult—an equally complete and intimate knowledge of the fishes themselves and of their various responses to the environment. Any factor is important to the extent in which it limits the life and abundance of any kind of fish. And, as a corollary, all factors are important at least as they exceed certain threshold limits.

Considerable information and observation on individual species, together with the quantitative data, make possible a rather critical analysis of some of the factors affecting fish distribution and abundance. Environmental factors known to be of importance in these small streams are: volume of water; depth of stream; rate of flow; permanency of stream (*i. e.*, whether or not it is reduced to pools in dry weather); submerged vegetation, shade, and other cover; kind of bottom; temperature variation; fertility of soil of drainage basin; pollution; and catastrophe (unknown factors which destroy or drive out whole species from within one or more stream systems). Biological factors known to be of importance are: migration, activity in winter (metabolism), morphological adaptation, physiological adaptation, diet, size, habit (*e. g.*, sedentary or active), disease, introduction of new kinds, association of species independent of the environment, association of species showing preference for same environment, predator-prey relationship, and modern and primitive groups.

Relation of Distribution and Abundance to Stream Size

All of the kinds of fishes with which we are dealing exhibit frequencies which vary with stream size in a very consistent and definite manner for each species. Small streams flowing into large streams have no more large-stream fishes than do small streams that increase slowly over many miles of length. It can be shown that some species which reach greatest numbers at certain points in a stream also reach greatest numbers in other streams at points with the same drainage area, without reference to distance from headwaters or from the mouth. In certain species the entire population is confined to a certain stream size with very narrow limits, while other kinds may occur in all sizes of streams but show abundances which fluctuate about a certain stream size as a mode. The young of some of the species of suckers have their greatest frequency in smaller streams than do the adults. In most fishes, other than the suckers, both the young and the adults occur most abundantly in the same size of stream.

Forbes and Richardson (1909) expressed the relation of stream size to the distribution of the different species by the relative frequency of occurrence in larger rivers, smaller rivers, and creeks. In their system of classification all of the streams of Champaign County would probably come under the general heading of creeks. Hankinson[6] used a similar method. Shelford[7], in considering this same subject of distribution of fishes in streams, has brought out most of the principal facts of the problem. One of the more important points he states is "that the different fish communities are closer together in the smaller streams."

Several methods for expressing in a statistical manner this greater proximity of fish communities in the smaller streams were tried. It was found that the most satisfactory method was to consider the streams in classes in which each class is twice the preceding class, that is, in a geometrical progression. Since the streams studied here varied in drainage area from 0.7 up to 378 square miles, they fell very conveniently into ten classes beginning with 0.5-1.0 and ending with 256-512 square miles. The validity of this method of classification is indicated in Fig. 6 where the number of species per collection and the number of fishes per square yard have been plotted from data given in the tables mentioned on page 17. As is commonly the case, the ends of the curves are based on smaller numbers of determinations and, hence, are more vari-

6. Hankinson, T. L., "Distribution of Fish in the Streams About Charleston, Illinois." Trans. Ill. Acad. Sci., 6:102-113, 1913.
7. Shelford, Victor E., "Ecological Succession. I. Stream Fishes and the Method of Physiographic Analysis." Biol. Bul. 21:9-34, 1911.

able. In order to smooth the curves the three classes at each extreme have been averaged and plotted, so that we now have points on the curves representing approximately equal numbers of observations. The fact that these two biological functions of stream size give curves that approximate straight lines is good empirical reason for assuming that this is the correct method for comparing the life of streams of widely varying sizes. There is the further convenience that the distribution of the collections in the different size classes is fairly uniform; whereas, if ten arithmetical classes of 0-40, 40-80, 80-120, *etc.*, had been used, more than two-thirds of the total number of observations would have fallen in the 0-40 class. It seems that this method of tabulation may be advantageously extended in biological studies to compare the range of adaptability of different species to different stream sizes, varying from the smallest we have mentioned here up to, let us say, the size of the Mississippi at New Orleans. If, for example, we find that the spoonbill cat

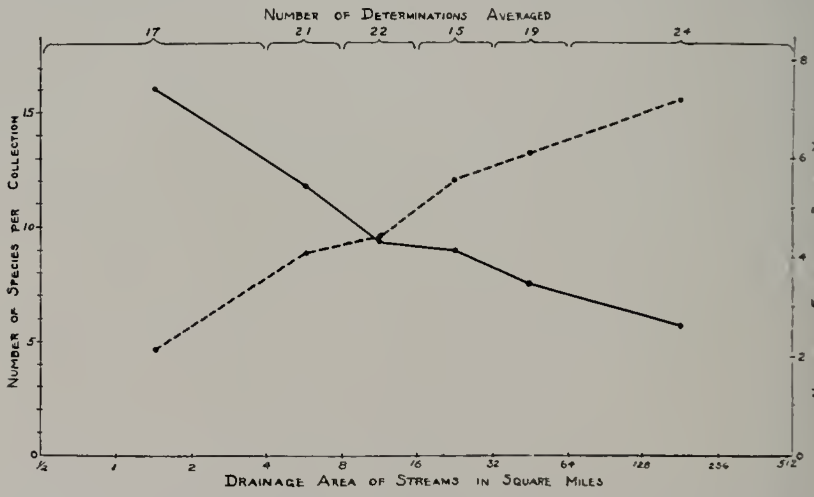

Fig. 6. Graph showing relation of variety and abundance of fishes to stream size. The solid line indicates number of fishes per square yard, and the dotted line number of species per collection.

inhabits streams of sizes varying over 8 *size classes* in this scale (*e. g.*, from the Mississippi at New Orleans up to Sterling on the Rock River in Illinois) and that the rainbow darter likewise ranges over 8 *size classes* (*e. g.*, in the headwaters of the Sangamon River in Champaign County) we may say that they have the same *range of adaptability* to stream size, even though the total range of the spoonbill cat is over two thousand miles of river and that of the rainbow darter is only twenty miles of creek.

In Tables I to VIII are given the frequencies of the different fishes taken in the 1928 collections in average numbers per 100 square yards for streams of each size. Nineteen of these species are obviously restricted in their distribution to certain stream systems. The average numbers per 100 square yards for these species are based only on those stream systems in which they occurred and not on the county as a whole.

Thus, in the case of *Erimyzon succetta oblongus*, the chub sucker, which occurs generally in all the stream systems, there are on an average 6.0 individuals per 100 square yards in streams with 8-16 square miles of drainage area; while in the case of *Hybognathus nuchalis*, the silvery minnow, which is restricted to the Kaskaskia River basin, there are on an average 5.6 individuals per 100 square yards in streams with 8-16 square miles of drainage area *and none elsewhere*.

Table I. SUCKERS—Average Numbers per 100 Square Yards.

Species	Drainage area of stream in square miles at point of collection									
	0.5-1	1-2	2-4	4-8	8-16	16-32	32-64	64-128	128-256	256-512
Erimyzon succetta oblongus	29.4		2.3	5.7	6.0	1.6	0.2	0.9	0.2	
Catostomus commersonii		6.6	1.2	35.7	9.0	2.2	7.2	9.5	2.1	1.1
Catostomus nigricans				0.1	0.8	0.7	1.5	0.4	1.2	0.6
Minytrema melanops					0.1			0.2	0.9	
Moxostoma aureolum				0.6		0.1	0.4	1.7	4.5	1.2
Moxostoma breviceps						0.1	0.2	0.1	0.2	0.1
Carpiodes velifer						0.5	0 1	0.2	0.4	0.3
Carpiodes difformis								0.9	1.1	0.2
Ictiobus urus									0.1	
Ictiobus cyprinella										0.1

Table II. MUD-EATING MINNOWS—Average Numbers per 100 Square Yards.

Species	Drainage area of stream in square miles at point of collection									
	0.5-1	1-2	2-4	4-8	8-16	16-32	32-64	64-128	128-256	256-512
Campostoma anomalum	14.0	92.0	6.7	96.5	29.8	11.3	13.3		5.3	1.7
Pimephales notatus	36.0	78.0	62.3	164.6	87.9	124.5	63.1	49.6	87.1	35.1
Pimephales promelas*				14.5	22.7	2.7	5.2	3.0	2.6	0.5
Hybognathus nuchalis†					5.6	6.3	5.0	10.0		

* Restricted to Sangamon River Basin.
† Restricted to Kaskaskia River Basin.

Table III. MINNOWS OF THE GENUS *NOTROPIS*—Average Numbers per 100 Square Yards.

Species	Drainage area of stream in square miles at point of collection									
	0.5-1	1-2	2-4	4-8	8-16	16-32	32-64	64-128	128-256	256-512
N. cornutus*		10.0	25.0	88.8	64.3	132.6	141.0	31.7	35.8	10.8
N. whipplii		4.0	1.1	8.1	2.3	20.1	7.9	12.1	50.5	54.3
N. blennius		2.0		1.5	2.5	14.0	57.7	18.7	28.9	21.7
N. umbratilis atripes				24.5	6.8	15.3	17.6	16.4	18.9	5.8
N. pilsbryi					0.7	1.1				
N. gilberti†						1.3	5.0			2.8
N. atherinoides-var.‡									9.0	
N. illecebrosus§									3.8	
N. cayuga									0.1	

* Restricted to Sangamon, Middle Fork, and Kaskaskia River Basins.
† Restricted to Sangamon River Basin.
‡ Restricted to Middle Fork River Basin.
§ Restricted to Middle Fork River Basin.

TABLE IV. OTHER MINNOWS AND THE CARP—AVERAGE NUMBERS PER 100 SQUARE YARDS.

Species	Drainage area of stream in square miles at point of collection										
	0.5	1	2	4	8	16	32	64	128	256	512
Semotilus atromaculatus	562.4	177.0	54.0	69.2	142.7	30.3	18.4	4.3	3.3	9.3	
Ericymba buccata	2.0	510.0		58.4	82.4	100.0	71.4	37.3	33.2	12.6	
Abramis crysoleucas	7.0	1.0	7.6	11.1	0.7	5.6	4.7	5.3	5.0		
Hybopsis kentuckiensis*			4.5	2.0	46.9	74.1	33.6	11.3	17.6	9.2	
Phenacobius mirabilis				0.5	0.1	1.3	2.4	1.6	2.2	1.7	
Hybopsis amblops†					0.1	0.5	0.2	4.4	2.4		
Opsopoeodus emiliae					0.1						
Cyprinus carpio							0.1	0.2	0.2	0.4	
Cliola vigilax‡								4.7	0.4	0.7	

* Restricted to Sangamon, Middle Fork, and Kaskaskia River Basins.
† Restricted to Middle Fork, Salt Fork, and Embarrass River Basins.
‡ Restricted to Sangamon and Salt Fork River Basins.

TABLE V. CATFISHES—AVERAGE NUMBERS PER 100 SQUARE YARDS.

Species	Drainage area of stream in square miles at point of collection										
	0.5	1	2	4	8	16	32	64	128	256	512
Ameiurus melas	750.0			22.3	0.1	0.6	0.1	0.2	0.2	0.1	
Ameiurus natalis				0.4	0.7	0.9	0.1		0.3		
Schilbeodes gyrinus*				0.2	0.6		1.2		0.2	0.2	
Schilbeodes miurus†							9.8				
Ictalurus punctatus							0.2		0.6	0.2	
Noturus flavus									1.0	0.1	
Schilbeodes exilis									0.1	0.2	
Leptops olivaris										+	

* Restricted to Salt Fork River Basin.
† Restricted to Salt Fork River Basin.

TABLE VI. SUNFISHES AND BASSES—AVERAGE NUMBERS PER 100 SQUARE YARDS.

Species	Drainage area of stream in square miles at point of collection										
	0.5	1	2	4	8	16	32	64	128	256	512
Lepomis megalotis	12.0			2.3	1.1	2.2	1.0	2.8	2.7	0.4	
Lepomis cyanellus	5.0	5.0	0.3	3.5	2.7	1.6	0.7	0.2	0.5	0.8	
Lepomis humilis*		1.2		0.7	0.2		0.7	2.2	1.3	0.1	
Micropterus salmoides				0.4					0.2		
Micropterus dolomieu						0.2	1.0		0.8	0.4	
Ambloplites rupestris							0.1		0.1		
Pomoxis annularis							0.1		0.1		
Pomoxis sparoides									0.2	0.2	
Chaenobryttus gulosus†							+				
Lepomis miniatus†							+				
Lepomis pallidus†							+				

* Restricted to Sangamon, Middle Fork, and Salt Fork River Basins.
† Single specimens of these three species were taken in the Salt Fork near the outlet of Crystal Lake from which they apparently have escaped.

TABLE VII. DARTERS—AVERAGE NUMBER PER 100 SQUARE YARDS.

Species	Drainage area of stream in square miles at point of collection 0.5	1	2	4	8	16	32	64	128	256	512
Boleosoma nigrum			1.0	5.9	8.9	21.3	15.2	16.3	16.3	8.2	3.3
Etheostoma coeruleum*				0.5	3.7	11.4	10.8	5.6		2.8	1.1
Hadropterus aspro				0.3	0.3	0.4	0.3	0.4		1.2	1.1
Etheostoma flabellare†					0.2	0.5	0.4	0.8		0.8	0.8
Boleosoma camurum						0.1					
Diplesion blennioides‡						+	0.1	0.1		11.5	0.1
Boleichthys fusiformis							0.1				
Hadropterus phoxocephalus							0.1			0.8	0.6
Etheostoma zonale§								4.6		1.8	7.7
Percina caprodes								0.1		0.2	
Ammocrypta pellucida¶										4.0	

*Restricted to Sangamon, Middle Fork, Salt Fork, Little Vermilion, and Embarrass River Basins.
† Restricted to Sangamon, Middle Fork, Salt Fork, and Embarrass River Basins.
‡ Restricted to Middle Fork, Salt Fork, and Embarrass River Basins.
§ Restricted to Sangamon River Basin.
¶ Restricted to Middle Fork River Basin.

TABLE VIII. MISCELLANEOUS FISHES—AVERAGE NUMBERS PER 100 SQUARE YARDS.

Species	Drainage area of stream in square miles at point of collection 0.5	1	2	4	8	16	32	64	128	256	512
Esox vermiculatus		3.7		0.1	0.9	0.9	1.5	0.8	0.3	0.2	
Fundulus notatus				1.4	2.0	3.0	8.7	2.3	0.4	1.2	0.6
Aphredoderus sayanus*					1.8	15.8	5.7		0.8		
Labidesthes sicculus†								0.1	3.2	1.2	
Hiodon tergisus									0.1		
Anguilla chrysypa									+		
Dorosoma cepedianum										+	0.1
Aplodinotus grunniens											0.4

* Restricted to Sangamon, Embarrass, and Kaskaskia River Basins.
† Restricted to the Salt Fork River Basin.

While each species seems to present a separate and often complex problem with regard to the precise effects of stream size on its distribution and abundance, the data make clear some relationships that are important to at least several species in common. Let it suffice, here, to state only a few of these: (1) The upstream limit for about one-third of the 74 species known in the county is the point above which a stream is reduced to a series of more or less shrunken pools during dry weather. At this point the drainage area of our streams commonly varies between 2 and 16 square miles, depending on the contour of the land, the character of the soil, and the drainage improvements. (2) Many species that habitually hide in submerged coarse aquatic vegetation, even though they show no marked preference for certain species of plants, are nevertheless limited to the distribution of the plants, which is likewise a function of stream size and physiography. (3) Certain darters and stone cats are limited to certain characteristic kinds of rocks for cover and to certain stream velocities and depths which are found only in streams discharging certain volumes of water. (4) The kinds and proportions of food available to fishes in streams of different sizes vary widely, and there are parallel variations in the distribution of many fishes which are restricted to certain food materials.

As shown in Figure 6 (page 42), the number of species of fishes *per collection* increases downstream. In one way this may seem to contradict Shelford's general statement that "communities" are closer together in small streams than in large ones, but it is explicable on the basis that the comparatively few species in the headwaters are *generalized* fishes, able to live and thrive under widely varying conditions. (A fuller discussion of these headwater fishes is given in the following section.) Then, too, the plurality of species downstream is largely due to species present in small numbers, except locally, in "niches" in the "mosaic" of the aquatic environment, where they find food and shelter without competition or invasion by larger, more numerous, or more generally distributed kinds.

The graph in Figure 6 also shows that the actual number of fishes *per unit area* decreases downstream. But with this decrease of number of fishes downstream there is a corresponding increase in the average size of the individuals, so that, other factors being equal, the total amount of fish flesh per unit area is probably almost constant. This apparent constancy of the amount of fish flesh per unit area is a fact of practical importance and is readily applicable to many fisheries problems, but it is also not without its philosophical interest. The life of streams is ultimately made up of rain water and non-living nutritive substances derived from the soil. This prospectively-living material is "crystallized out" in the form of bacteria and other lower forms of plant life, very much as a salt is crystallized out of a supersaturated solution when the process is started by the addition of a crystal of the salt; and this "crystallization" goes on until an equilibrium is established. The bacteria and other lower forms of plant life which are nourished by non-living material are the beginning of a long chain of organisms, each feeding on the one before, and their interrelations approaching an equilibrium. Fishes commonly are the end of this food chain in water. The efficiency with which each stage in the chain utilizes the preceding one varies widely. The bacteria and other lower forms of plant life probably are efficient in utilizing non-living nutritive material, and they in turn are apparently utilized efficiently by the common plankton organisms, but beyond this point a discrepancy arises. Some determinations made by Mr. R. E. Richardson, on the relation of the fish yield of Rock River to the yield of plankton there, have showed that the fish yield represented the efficient utilization of only a fraction of one per cent of the available plankton, although comparison of careful and detailed quantitative determinations of the yield of the small bottom animals upon which most fishes feed with the yield of fishes shows no large discrepancy. The greatest inefficiency, or discrepancy, is undoubtedly between the plankton and the small bottom animals. For the latter can take only such plankton as comes to them on the bottom; they cannot forage in the plankton-laden water flowing by overhead. Obviously, what is needed to make our streams more productive in fish is a new link in the food chain between plankton and the small bottom invertebrates.

HEADWATER FISHES

A few kinds of fishes can withstand the rigorous conditions of extreme headwaters, but these few species are abundant in numbers of individuals. These species are:

Erimyzon succtta oblongus—Chub sucker
Catostomus commersonii—Common sucker
Campostoma anomalum—Dough-belly
Pimephales notatus—Blunt-nosed minnow
Semotilus atromaculatus—Horned dace
Ericymba buccata—Silver-mouthed minnow
Abramis crysoleucas—Golden shiner
Ameiurus melas—Black bullhead

These fishes must withstand water temperatures in summer up to and exceeding 90°F. while living in pools so shrunken that the fish population is more than 10 times ordinary concentrations. In summer and early autumn they must withstand wide daily variations in temperature. In winter their ambient medium is largely converted into ice. In both winter and summer they may be called upon to endure lack of oxygen, excess of carbon dioxide, or extremes in hydrogen-ion concentration. At any season there may be torrential rains or sudden thaws that can in a single hour change their environment from a hot, stagnant pool or ice-covered ditch to a flood of muddy trash-laden water or a temporary pond in a field. When the water subsides, all the old landmarks may be gone, or the channel may have been shifted or filled up or cut deeper. Most other fishes, if called upon to meet such a crisis in the dead of winter with the water temperature at freezing, would be so torpid and sluggish in their movements that they would either be washed tail-first downstream or else be left stranded in some cornfield when the flood subsided.

The supply of animal food for headwater fishes is probably haphazard at best and depends largely on terrestrial insects which fall into the water in summer and on worms, insect larvae, etc., washed in by rains. In headwaters plankton has not had time to develop and very few kinds and scanty numbers of invertebrates are apparently able to withstand the conditions. All of these fishes seem to have solved the food question by having a very generalized diet. They all eat vegetation, organic debris, or bottom ooze probably as occasion demands, and animal food when they can get it, for none of them will refuse a bit of worm in an aquarium or on a tiny hook.

These are generalized fishes, apparently capable of meeting all situations and reaching large numbers under conditions more rigorous than others can endure. They are generalized morphologically and have a wide range of physiological adaptability. They are found over a wider range of freshwater habitats than other fishes. They not only tolerate pollution but in sizable streams can reach large numbers to the exclusion of other species where pollution is moderate.

Morphological adaptation, degree of isolation, tolerance to pollution, and other phases of the biology of these fishes are discussed in other sections of this paper.

RELATION OF SOIL FERTILITY TO GROWTH AND ABUNDANCE OF FISHES

This study was undertaken and carried on with the rather well founded assumption that the streams of Champaign County offer an unusual degree of uniformity of conditions. The data on abundance and size of fishes, however, show a wide divergence between Spoon River, or the East Branch of the Salt Fork, and the rest of the county. The greater concentration of fishes found in Spoon River was not due to a lower stage of water there than in the other streams; for all of the 16 collections in this stream were made at about an average stage of water and were distributed as follows: 5 in July, 4 in August, and 7 in September. The total area covered in these collections was 817 square yards, about 8 percent of the total area covered in our quantitative collections throughout the county. The number of fishes taken from these 817 square yards was 4,566, or more than 5 per square yard as against the average of 3 fishes per square yard for the whole county. Thus, on an average, fishes were twice as numerous here as in the county as a whole. Again, the total weight of the fishes taken from this stream was about 110 pounds, or 37 percent of the total weight taken in the county, although the number of individuals was only 16 percent of the total number taken. That is, the individual fishes averaged from 2 to 3 times as heavy here as in the county as a whole. A comparison of the average number of fishes per 100 square yards at various points on the East Branch of the Salt Fork and its tributaries with average numbers at similar points for the county as a whole (except the polluted part of the Salt Fork, where fishes are very scanty) is shown in Table IX.

The 34 species taken in the East Branch of the Salt Fork constitute a list somewhat longer than from similar numbers of collections in other streams of the same size-range in the county. The greater number of specimens taken seems to account satisfactorily for the longer list of species. A comparison of the average number of species per collection in this stream and in the county as a whole is given in Table X.

It is interesting to see to what extent each of the different species contributed to the increased number and size of fishes in this area. Of the 34 species found in this stream, 25 occurred in abundances greater than the average for the county as a whole, and 20 of the latter in abundances greater than twice the average for the county as a whole. The silver-mouthed minnow, *Ericymba buccata*, exhibited the greatest numerical preponderance over the average for the county, contributing 1,480 of the 3,519 specimens of this species taken in the county. This preponderance is readily explained by its preference for a sandy bottom, of which this stream has much larger areas than are to be found elsewhere. The horned dace, *Semotilus atromaculatus*, here furnished 940 out of its total 2,873 taken in the county, and the Johnny darter, *Boleosoma camurum*, 309 out of 993. It should be noted that none of the species of *Notropis* were more abundant here than the average for the county at large.

The increase of the total weight of fishes in this stream is even more notable than the increase in numbers, being 4 to 5 times the average for the county as a whole. The greatest increase in this weight was shown by the black sucker, *Catostomus commersonii,* which was not only 3½ times as abundant here as in the county at large, but also averaged about three times as large individually. The average size of a number of other species is obviously greater than in other streams.

The larger number and the larger size of fishes in this area indicate that the conditions for survival and growth are more favorable here, and it seems most probable that an increased food supply is the cause. An examination of the stomach contents of a number of the black suckers, *Catostomus commersonii,* showed quantities of blackish mud and

Table IX. Abundance of Fishes in Relation to Soil Fertility.

(Numbers per 100 square yards of water)

Stream size (drainage area in sq. mi.).	Number of collections.	Average of all Champaign County collections except polluted part of Salt Fork.	Average of collections in polluted part of Salt Fork (Disposal Plant to County Line).	Average of collections in East Branch of the Salt Fork where the soil is very fertile.
0.5				
	5	1419		2840
1				
	5	880		1732
2				
	7	160		
4				
	21	545		1228
8				
	22	429		953
16				
	15	413		1571
32				
	19	346		540
64				
	7	270	11	915
128				
	11	323	*	471
256				
	6	208	30†	
512				

* Two collections taken in this region give an average of 238 per 100 sq. yds. They are omitted because 92% of this number are of three tolerant headwater species which were evidently feeding here on an immense growth of diatoms and blue-green algae which extended from the mouth of the East Branch downstream for about five miles. Sixty-two per cent of the total number making up these two collections were taken at a single dip of the net in a small deep hole away from the main channel.

† This number is based on four collections made from Sidney down to the County Line, but does not include a collection made just below the Homer Dam, with 254 per hundred sq. yds., which would have brought the average up to 75 per 100 sq. yds. The latter collection is omitted because it yielded a number of species unusual to this part of this stream and because Richardson has shown that swift water offers unusual protection to otherwise sensitive forms.

ooze and little else. In this stream there were considerable amounts of a variety of aquatic vegetation, perhaps no greater than are to be found in other parts of the Salt Fork or in other streams, but of kinds better adapted for supporting an abundance of animal food for fishes. Collections of the small bottom animals, while not quantitative, indicated a much larger supply of fish food.

An inquiry addressed to Mr. E. A. Norton, of the Soil Survey, brought the information that the soil of this region was unusually fertile in plant foods, produced superior crop yields, and had a very different history from soils in the remainder of the county. This has been discussed earlier (page 7).

The abundance of fishes in this stream is apparently reflected in the fact that we took more adult snapping turtles, *Chelydra serpentina*, in this stream than in all the rest of the county combined. This is significant because the snapping turtle is almost, if not entirely, piscivorous in its habit.

Champaign County is near the center of an area of several counties in which the soil is more fertile than in other parts of the state. This area, as outlined by Mr. Norton, is shown in Figure 2. From it streams flow outward in different directions—the Kaskaskia and Embarrass to the south, the Sangamon and Mackinaw to the west, the Vermilion (a branch of the Illinois) and the Iroquois to the north, and the Big Vermilion and the Little Vermilion (branches of the Wabash) to the east. A casual examination of the distribution maps of Illinois fishes as given in the atlas accompanying the volume by Forbes and Richardson (1909) shows a decided preponderance of occurrences in this fertile area. A small part of this preponderance may conceivably be explained by greater numbers of collections in this area, but even so the occurrences are still more numerous in this area. Moreover, as we have just seen earlier in this section, if the number of occurrences is greater, the actual number and size of fishes is greater still. It is interesting to note that the 25 species of fishes which occurred in the East Branch of the Salt Fork in numbers greater than the average for the county are the *same species* which show unusually high percentages of occurrences in this unusually fertile general area as compared to the figures for the state as a whole.

Effects of Pollution on Growth, Distribution, and Abundance of Fishes

When this study was begun it was known in a general way, from casual collecting during the past ten years, that certain streams in Champaign County carried pollution and that aquatic life in these streams was more or less completely altered thereby. Previous experience in aquatic work outside the county had shown that household sewage, within certain limits, acts as a fertilizer and increases the productivity of a stream, the fishes being of greater size, abundance, and variety—a result comparable to the effect of high fertility of soil just described in the East Branch of the Salt Fork. The present study shows that an excess of sewage results in decreases of number of kinds, abundance per unit area, and average size of fishes. There is no lack of fertility or of plant and animal foods for fishes in these polluted streams, but the fishes cannot tolerate the conditions or substances that result from the sewage or its products of decomposition.

The most obvious and most important factor limiting fish life in polluted waters is the deficiency of dissolved oxygen which occurs in certain places and under certain conditions. Some work done a few years ago on the oxygen requirements of fishes of the Illinois River[8] showed that the number and variety of kinds of fishes taken by certain uniform methods of fishing in the same area varied directly with the amount of oxygen dissolved in the water. Furthermore, this variation in relative abundance and number of kinds not only took place in response to variations in the oxygen concentration near the lethal limit but was, apparently, equally as effective near the saturation point of atmospheric oxygen in water.

It is obvious that the size of fishes in these, as well as in other small polluted streams, averages distinctly smaller than in clean streams.

TABLE X. AVERAGE NUMBERS OF SPECIES OF FISHES PER COLLECTION.

(The average number of individuals per collection was about 220.)

Stream Size (drainage area in square miles).	Number of collections.	Average of all collections except polluted part of Salt Fork River.	Average of polluted part of Salt Fork (Disposal Plant to County Line).	Average of East Branch of Salt Fork, where the soil is very fertile.
0.5–1	5	3.8		3.0
1–2	5	5.0		6.5
2–4	7	5.0		
4–8	21	8.8		9.5
8–16	22	9.6		9.8
16–32	15	12.1		7.0
32–64	19	13.3		20.0
64–128	7	11.3	2.6	16.0
128–256	11	20.1	12.5	25.0
256–512	6	15.5	7.8	

8. Thompson, David H. "Some Observations on the Oxygen Requirements of Fishes in the Illinois River." Ill. Nat. Hist. Surv. Bul., vol. 15 (art. 7), pp. 423-437. 1925.

In the Illinois River it has been shown that the carp average smaller in the more polluted sections,[9] and this difference in size was found to be due to slower growth of the carp in those sections. In Champaign County streams, however, there is no evidence that the difference in size is due to slower growth; it seems somewhat more probable that the larger fishes are eliminated by low oxygen concentrations, since they have a smaller ratio of respiratory surface to body size than do small fishes.

The Salt Fork, which carries wastes from Urbana and Champaign, the largest towns in the county, is obviously polluted over a greater distance, and affords more complete information on the relation of pollution to fishes, than other streams in the county.

For comparison of the polluted and unpolluted sections of the West Branch of the Salt Fork, collections were made, at first, from approximately equal areas above and below the source of pollution, extending from the point where the stream enters Crystal Lake Park to the bridge just south of University Woods. In this distance the drainage area increases from 59 to 76 square miles, the difference being due primarily to the confluence of the Boneyard. The width, depth, rate of flow, and kind of bottom are essentially the same throughout this distance, so that the same variety of habitat is afforded above and below the source of pollution, namely: long, smoothly flowing reaches, separated by small rapids or riffles, and occasional "holes" three or more feet deep. The results of quantitative collections made from 330 and 320 square yards, respectively, above and below the source of pollution, are shown in Table XI. Other fishes known to have been taken from the stream in Crystal Lake Park during the year are indicated as "+" in this table. Most of the fishes taken below the Champaign-Urbana sewage disposal plant were about the mouths of two tile drains.

The differences in the fish life above and below the outlet of the sewage disposal plant are clearly due to conditions resulting from pollution in the lower section. The stream as it runs through Crystal Lake Park and down to the mouth of the Boneyard is typical of the clean dredge ditches of this region.

On May 10, 1928, at three points 1½, 3, and 5½ miles below the outlet of the plant, where the above collections of fishes from the polluted area were made, the stream had a nauseating odor perceptible on the bridges above the water. The stream was then quite low, and the weather was ordinary, warm, May weather. The rocks and other objects in the water at these three stations were covered with grayish or brownish feathery or flocculent growths. There was a large amount of light flocculent solid matter drifting in the water, sufficient to completely clog our seine when it was held in the current more than a few seconds. In the quieter places along shore and behind drifts and large objects, there were deposits of black sludge, varying from an inch to several inches in depth, which gave off a strongly putrescent odor when stirred up. Tubificid worms, which in numbers are characteristic of heavily polluted waters, were extremely abundant in the mud and sludge along the shores and also among the gravel and sand in midstream.

9. Thompson, David H. "The Knothead Carp of the Illinois River." Ill. Nat. Hist. Surv. Bul., vol. 17 (art. 8), pp. 285-320, with 11 fig. 1928.

On the riffles and in swift water there were considerable growths of two plants tolerant of pollution—*Cladophora glomerata* and *Elodea canadensis*—which, together with *Potamogeton pusillus* and one or two others, are characteristic of the coarse aquatic vegetation of polluted small streams of Illinois.

During the summer of 1928 there were heavy rains which largely flushed out the accumulations of sludge and organic matter from the stream bed, and the continuous operation of the disposal plant tended to reduce further accumulations. When collections were made in September it was expected that the stream would appear cleaner and fishes more abundant, but such was not the case. One small, blunt-nosed minnow *(Pimephales notatus)* and two very small green sunfish *(Lepomis cyanellus)* were collected from a total water area of 90 square yards in the same places in which the spring collections were made. There was no floating or drifting organic matter or sludge,

TABLE XI. EFFECTS OF POLLUTION IN THE WEST BRANCH OF THE SALT FORK.

Comparison of the kinds, numbers, and maximum sizes of fishes taken from approximately equal areas of water in the West Branch of the Salt Fork above and below the source of pollution on May 10 and 11, 1928. (See text, p. 52.)

Species	Collection from 330 square yards above source of pollution.		Collection from 320 square yards below source of pollution.	
	Number of fishes	Max. size in inches	Number of fishes	Max. size in inches
Notropis whipplii	+		1	1.8
Pimephales notatus	320	3.0	1	1.1
Semotilus atromaculatus	22	6.1	1	2.0
Notropis umbratilis atripes	71	2.5	18	2.1
Ericymba buccata	126	2.3	2	2.0
Campostoma anomalum	5	4.8		
Abramis crysoleucas	74	5.1		
Erimyzon sucetta oblongus	3	5.4		
Catostomus commersonii	6	9.8		
Esox vermiculatus	1	8.0		
Lepomis megalotis	12	4.3		
Lepomis cyanellus	7	5.1		
Lepomis humilis	3	2.3		
Lepomis pallidus	1	4.6		
Boleosoma nigrum	6	1.2		
Notropis blennius	+			
Ameiurus melas	+			
Labidesthes sicculus	+			
Lepomis miniatus	+			
Etheostoma flabellare	+			

such as was seen on May 10, and no large beds of sludge, but the sand and the mud of the bottom and banks contained a large admixture of black sludge with a putrescent odor and immense numbers of tubificid worms. The stream gave off the same nauseating odor as was noticed in May. The water was unusually clear for a stream in this region, possibly from the lack of fishes that tend to stir up the sediment and bottom muds, or else because of the agglutination and precipitation of the silt by the abundance of microscopic organisms poured in by the disposal plant. Downstream from the disposal plant outlet to a point several miles below St. Joseph, there was a heavy growth of brown diatoms; and for several miles below the confluence of the East Branch of the Salt Fork, there were heavy growths of blue-green algae along with the diatoms.

Collections made in September, 1928, from the West Branch and the East Branch, at stations 1½ miles above their confluence, yielded in the West Branch 30 fishes, taken from about 105 square yards, all of them belonging to four known tolerant kinds and having a total weight of about three ounces—as against 437 fishes, of 25 kinds, taken from 90 square yards in the East Branch and having a total weight of about 15 pounds.

In January, 1926, when the sewage disposal plant had been in operation about a year, a collection of fishes was made in the West Branch of the Salt Fork at the bridge just south of University Woods at the same place where the collections were made in the spring and fall of 1928. At this time fishes were clearly more numerous than they were found at any time in 1928. The number of kinds and the maximum size were greater, and specimens were taken of the Johnny darter, a species that has not been found since in the polluted section of the West Branch, although it is more tolerant than other darters. The 1926 data, though fragmentary, at least make it clear that four years of operation of the sewage disposal plant have had no greater effect than one year in cleaning up the stream.[10]

Dr. T. H. Frison reports that, in the years 1912 to 1914, sunfish, bullheads, and suckers could be taken in fair numbers on hook and line from the West Branch of the Salt Fork near the University Woods.

Collections made by the Natural History Survey in the West Branch of the Salt Fork in the period 1882-1901 showed a number of species not found in the 1928 collections, even though the latter collections were twice as numerous. In the older collections the white crappie and the large-mouth black bass were taken, probably because they were planted or had escaped from a fish hatchery which was then in operation in Urbana. Besides these, the spotted sucker, common red-horse, sucker-mouthed minnow, top minnow, brook silverside, and black-sided darter have since disappeared, even from the stream above the source of pollution. It so happens that the stream above the source of pollution is just at the upper limit of stream size in which all of them live, except perhaps the last named; and since the stream below Urbana has become heavily polluted, they apparently have not been able to exist and maintain their numbers cut off from the lower course of the stream.

10. In the past two years the plant has been operated continuously, and new units have been added which tend to reduce further the organic load of the stream. A few cursory examinations made recently reflect these improvements, there being a somewhat greater variety and greater numbers of fishes, particularly in the lower course of the stream.—D. H. T. July 1, 1930.

Collections of bottom fauna and plankton were made in the West Branch near the University Woods in May, 1929, and were identified in the laboratory by Mr. Richardson. The bottom fauna collections were made from clumps of *Elodea canadensis* growing in midstream and from gravel and sand there. The most numerous animals taken from these were two species of sludge worms, or Tubificidae. *Limnodrilus hofmeisteri* and *Tubifex tubifex*, which occurred in roughly 100 times the numbers to be expected in ordinarily clean streams with gravel and sand bottom. The presence of these sludge worms in such numbers is indicative of a heavy load of organic matter in the water and, in general, conditions which are distinctly pollutional. Small numbers of several other species of small bottom animals also occurred in these collections, but their value as indices of pollution has not been sufficiently studied. One other thing was noticed which invariably indicates foul conditions—the larvae of the sewage fly, *Psychoda alternata*. Furthermore, other insect larvae found here were covered with colonial vorticellid protozoans of the genus *Epistylis*. In unpolluted streams the insect larvae and other small bottom animals are habitually clean and free from incrusting microörganisms. The plankton sample taken here showed *Epistylis*, *Thiothrix*, and *Rotifer tardus*, all of which were probably washed down directly from the sprinkling filter bed of the sewage disposal plant.

Determinations of the amount of dissolved oxygen in the polluted section of the Salt Fork, made at various times during the past two or three years, showed amounts varying from saturation down to 3 or 4 parts per million. In those cases where a series of samples were taken on the same day at different points on the stream the samples showing least dissolved oxygen were taken near the outlet of the plant. Duplicate samples taken on January 17, 1929, at a point 1½ miles below the plant, showed a biological oxygen demand of 51 and 56 parts per million. At that time the plant was discharging at the rate of 2,700,000 gallons per day, and the effluent was diluted to 6 times that volume by the water in the stream.

Occasional periods of oxygen deficiency are usually regarded as the immediate cause of destruction of fishes by pollution. Evidence of this came to hand in November, 1928, during other studies along the West Branch of the Salt Fork from the bridge east of the Tuberculosis Sanatorium down to Brownfield Woods, points respectively 1½ miles and 3 miles below the sewage disposal plant. In the early part of the month the stream had been low and there were considerable accumulations of sludge and putrescing organic matter along the shore and in the quieter places. On the 14th and 15th of November, as a result of rains, the water level rose and the sludge and organic matter were stirred up. At this time the stream was black, smelled strongly putrescent, and had the appearance of being septic. On the 16th and 17th the stream had subsided and resumed its customary aspect. On these days several small fishes were picked up freshly dead; they were faded and had their mouths agape and their opercles and branchio-stegals extended, showing evidence of suffocation. Since lack of oxygen is the only well-known means by which pollution has its effect on fishes, it seems that lack of oxygen must be at least the tentative explanation of the absence of fishes in this stream.

The West Branch of the Salt Fork from the sewage disposal plant down to its confluence with the East Branch receives no tributaries other than a few tile drains. In this stretch of about 12 miles the condition obviously improves, fishes become more numerous, of more kinds, with greater maximum size; and the deposits of sludge, the nauseating odor, and the other evidences of pollution decrease. It seems quite certain that this improvement in the stream without much dilution is due to the continuance and completion of biological processes of self-purification.

A collection made in September, 1928, about 2 miles below the confluence of the East Branch and West Branch of the Salt Fork, showed fishes in normal numbers, but 98 percent of them were of known tolerant kinds, 92 percent being blunt-nosed minnows, silver-mouthed minnows, and steel-colored minnows, which were feeding on the very heavy development of diatoms and blue-green algae at this point. From Sidney down to the county line, fishes occurred in about one-seventh of the numbers normal to streams of this size. Apparently normal numbers and kinds of fishes were taken just below the Homer Dam, but Richardson (1928) has shown that swift water, in general, offers unusual protection to species otherwise sensitive to pollution.

During the period 1919 to 1924, *i. e.*, before the sewage disposal plant was put in operation, the writer collected fishes from time to time in the two-mile stretch above the Homer Dam. Fishes taken then included green sunfish, long-eared sunfish, suckers, bullheads, and several kinds of minnows. When those collections are compared with collections made in the same place in 1928, no obvious increase in fishes is apparent, although several car-loads of fishes have been planted there since the disposal plant was put in operation. There are reports of crappies, carp, channel cat, bullheads, and many sunfish being taken above the Homer Dam in 1916.

The number of species of fishes and the abundance of each in the polluted part of the Salt Fork, as compared with other streams of the county, are shown in Tables IX and X.

The following list of fishes, arranged in order of decreasing tolerance to pollution in small streams, is based on observations in this and other streams of comparable size:

Semotilus atromaculatus
Pimephales notatus
Notropis umbratilis atripes
Ericymba buccata
Notropis whipplii
Abramis crysoleucas
Lepomis cyanellus
Boleosoma nigrum
Campostoma anomalum
Erimyzon sucetta oblongus
Catostomus commersonii
Notropis cornutus
Hybopsis kentuckiensis
Notropis blennius

The darters other than the Johnny darter seem to be most sensitive to pollution. Almost all of these tolerant species find their greatest development in headwater streams. These headwater species occur in polluted large streams where they normally would not occur in such numbers were the stream clean.

The Boneyard, a small creek flowing through Champaign and Urbana and emptying into the West Branch of the Salt Fork about a half-mile above the outlet of the sewage disposal plant, has been badly polluted with a miscellany of household and industrial wastes including oils, gas liquors, tar, soap suds, rubbish, garbage, precipitates from water-softening processes, drainage water from the streets, etc. This stream is practically without fish, there having been reported within the past few years a medium-sized black sucker, three or four very small chub suckers, and a school of about a dozen small minnows. The effect of the Boneyard water on the fishes of the stream below was not separated from the effect of the effluent of the disposal plant in the present study.

Copper Slough, a branch of the Kaskaskia, receives untreated sewage from the west part of the city of Champaign and is thereby so grossly polluted for several miles down from its source that there was no fish life at all in August, 1928, and even in its lower course there were very reduced numbers of fishes. Dr. T. H. Frison reports that some years ago black bullheads and horny-head chubs could be taken where Route 10 now crosses Copper Slough.

Sewage from the village of Rantoul flows eastward about two miles in a ditch alongside the highway and empties into the East Branch of the Salt Fork. It was noticed at the time of our first visit, in July, that the ditch coming from the town (carrying undiluted sewage) stank badly and was black with sludge, and that grayish growths of pollutional protozoans or schizomycetes were abundant. The weather just then was very warm, and by the time the sewage had reached the stream the putrefactive processes were evidently nearly complete; for the stream below the mouth of this ditch was not septic, although there were extensive deposits of sludge and an obvious scarcity of the bottom animals ordinarily found in clean streams. Fishes were abundant in the stream below the mouth of the ditch, a quantitative collection made there showing 1,866 per 100 square yards—a figure which compares well with abundance figure for other headwater streams feeding the East Branch of the Salt Fork. It should be mentioned, however, that 94 per cent of the fishes in this collection were of known tolerant kinds. The same place was visited again in November after the weather had been near freezing for some days. Although the water level in the ditch and in the stream was at approximately the same stage as in July, the coolness had retarded the putrefactive processes so that they were, apparently, only well under way by the time the stream was reached; for the stream itself was stinking and septic and entirely without fishes for 1½ miles below the mouth of the ditch.

A few years ago many fishes were killed in a tributary of the Sangamon as the result of pollution by wastes from a canning factory near Gibson City.

Other Environmental Factors Affecting Distribution and Abundance

Vegetation is a factor determining the abundance of most small-stream fishes. The largest variety and greatest abundance of fishes in individual collections were consistently found in situations with luxuriant growths of submerged coarse aquatic plants. The large number of fishes in such places is certainly correlated with the large populations of food organisms which these plants support. The presence or absence of certain species, such as the pirate-perch, the golden shiner, and the grass pike, is closely associated with the presence or absence of aquatic vegetation.

Depth of water is an important factor in the distribution of many fishes. The buffalo fishes, carp-suckers, gizzard shad, sheepshead, and several of the sunfishes are found only in the deeper pools. Others, such as the long-eared sunfish, may occur in a stream of any size in the county providing that the water is a foot or more in depth. In general, adult fishes seek deeper water than young fishes, and large species more than small species.

Kind of bottom and rate of flow of streams in Illinois generally are casually related, and it is difficult to differentiate the effects of these two factors on the distribution of fishes. Some species are obviously more abundant on certain kinds of bottom than on others, and a few are very strictly limited to certain substrates, as is described in various places in this paper. Our present data do not permit a critical comparison of total abundances of fishes on different kinds of bottom, and no obvious consistent differences were apparent during the course of the field work.

Effect of Fish-eating Species on Abundance

The general decrease in number of fishes and increase in size of individual fishes as we pass from the smaller to the larger streams may be due, at least in part, to the larger number of fish-eating kinds in the larger streams, such as the large-mouth and small-mouth black bass and the channel cat. Our numbers of these kinds are too small to make a statistical comparison. One of the most voracious of the typically small-stream fishes is the grass pike. Excluding collections from the polluted part of the Salt Fork, our 26 collections in which the grass pike occurred averaged 2.49 fishes per square yard; and the remaining 86 collections, in which the grass pike did not occur, averaged 5.71 fishes per square yard—more than twice as many. The number of grass pike producing this effect was quite small, averaging only 0.006 per square yard. This relatively large effect of so few grass pike is understandable, however, because we have aquarium experiments which show that a grass pike of average size can eat about one minnow per day.

Some Observations on Morphological Adaptations

Since the beginning of the science of biology, close organic correlation of the various parts and internal functions of an organism during its life history has been so apparent and so exact that workers in this field are much given to teleological explanations of these phenomena.

Workers investigating the relations of organisms to their surroundings are much more impressed by the similarity of the reactions of the different organisms in a given environment than by the similarity of morphological adaptations found there. In this they are doubtlessly correct. Morphological adaptation, however, should not be neglected or put aside as unimportant.

Among the small-stream fishes of Champaign County it has been found that there is a readily recognizable and fairly close correspondence between habit and structural adaptation, although there are many exceptions. Non-adaptive structures, incongruities, elaborateness, and uniformity of detailed structure are certainly not necessary from the standpoint of the requirements of the environment; nevertheless, they are the rule within the various races of animals and are intimately tied up with the fundamental nature of living substance itself. The relative importance of physiological as against morphological adaptations is a dilemma that has been considerably clarified by recent findings in the study of the manner of inheritance of the characteristics of living things. It has been found that many morphological changes are *inseparably associated* with certain physiological qualities. It so happens that the morphological changes are usually of trivial importance from the standpoint of viability and usually involve such things as proportion of parts, texture, color pattern, etc. The associated physiological qualities, on the other hand, commonly involve such important things as number of eggs, length of life, rate of development, viability at all stages, reactions to stimuli, etc. If both the physiological and morphological changes are of advantage they will survive. If both are disadvantageous they will not survive. However, if one is advantageous and the other disadvantageous the one will survive which has the greater selective value at critical points in the life history, and the other will be carried along willy-nilly because it is inseparably associated, even though it is unnecessary or even somewhat disadvantageous. The fact that hereditary changes usually involve selective differences which are more often physiological than morphological, gives a hint as to why animals show a better physiological than morphological closeness-of-fit to the environment.

The fishes of Champaign County fall into three approximately equal groups with respect to current: (1) Those that live in the faster, shallower water and spend most of their time, not swimming, but clinging to the bottom or hiding behind or under objects which break the force of the current. (2) Those that live in deeper and more sluggishly moving water and spend most of their time swimming or floating but not clinging or hiding. (3) Those that inhabit both kinds of places and divide their time between clinging or hiding and swimming freely. As these three groups of fishes are examined, certain morphological features stand out as characteristic of each group.

The first group—"clinging" fishes—is typified by the hog sucker, the darters, the red horses, the stone cats, and the tadpole cats. They have a large head and a body that tapers from the head to the tail and is roughly circular in cross-section; that is, they are slenderly conical. They have large pectoral fins with which they cling or "crawl" on the bottom. Their specific gravity is greater than that of other fishes. They often show protective coloration by having their backs crossed by dark bars.

The second group—"swimming" fishes—is typified by the gizzard shad, the toothed herring, the sunfishes, and certain minnows such as *Notropis cornutus, N. umbratilis,* and *N. whipplii.* These fishes are flattened laterally and tend to taper equally toward the head and tail from the middle of the body. Their swimming habits are correlated with large caudal fins and a specific gravity almost exactly the same as water. These are the fishes that leap from the water. Adults of several other species have the body shape and swimming habit of this group, but their young live in fast water and have the body shape typical of the first group. An excellent example of such a change in body shape and habit is found in the silver carp, *Carpiodes velifer.*

The third group—"generalized" fishes—has a body form typified by the extreme headwater fishes, such as the blunt-nosed minnow, the horned dace, the chub sucker, and the dough-belly. These fishes tend to be circular in cross-section and to taper from the middle toward both ends. They are commonly found in both still and fast water.

While there are many exceptions in one way or another to the above classification, it still holds for most of the local fishes.

There are other local examples of structural adaptation correlated with certain habits. Fishes that regularly feed from the surface, such as the silverside *(Labidesthes sicculus)* and the top minnow *(Fundulus notatus)*, have flat backs and upturned mouths. Larger fishes that habitually live under flat rocks, such as the stone cat (*Noturus flavus*), are dorso-ventrally flattened. Fishes that nuzzle the bottom and pry among rocks for food, such as the various suckers and the sucker-mouthed minnow (and elsewhere the sturgeons), have inferior, protrusible mouths. There are three species of one genus (*Ictiobus*) which are bottom feeders but have differently formed mouths: the small-mouth buffalo has a strictly inferior mouth, the mongrel buffalo has a mouth tilted up at about 22° from the horizontal, and the red-mouth buffalo has its mouth turned up at an angle of 45°. In late summer large numbers of red-mouth buffalo have been seen sucking in the foam and floating insects in the quieter eddies of Rock River, but never a mongrel or a small-mouth buffalo. This observation is amply borne out by recent studies of the stomach contents of these three species.

MIGRATION, ISOLATION, AND CHANGES IN DISTRIBUTION

The extremes of fish migration are represented by fishes taken in Champaign County. As one extreme, there is the eel taken in the Embarrass River, which must have been spawned in the Sargasso Sea off the coast of the Bermuda Islands, according to recent life-history work on this species. As the other extreme, we have darters that live under the rocks on riffles and may not have moved more than a few hundred yards in many generations.[11] The migration of most of our species, however, is moderate.

11. A good instance exemplifying this sedentary habit came out during our work on the Rock River. In 1927, after four years of collecting in the Rock River basin, it seemed that our list of fishes was complete, at least for the basin in Illinois. I went to see two old fishermen, brothers by the name of McMillan, who had made most of their living since boyhood by fishing one way or another in the vicinity of Rockford. In order to facilitate conversation and avoid difficulties of different common names for the same fish and the same common name for different fishes, I took along the Survey's illustrated volume on the fishes of Illinois. We

We have sufficient information to show migration for eight species of suckers, the young of each of these species being regularly taken much further upstream than the adults. As an example, the young of the common red-horse were found most abundantly in streams draining 4 to 8 square miles, while the adults are known to reach their greatest abundance in streams draining 1,000 or more square miles, *i. e.*, much larger than any in Champaign County. The toothed herring and the gizzard shad probably make migrations of about the same order in larger streams, and the larger members of the sunfish family are probably capable of extended migration, although our data do not directly indicate this. Among the minnows there are no clear examples of different distribution of the young and the adults in our streams, but a certain amount of migration is indicated by the fact that headwater minnows are regularly found in spring in small rivulets which at other seasons dry up completely for one or more miles. None of our seven species of catfishes gave evidence of any considerable migrations.

During 1928 and 1929, several anglers fishing in the Sangamon River, both in Champaign County and Piatt County, have expressed surprise at taking sheepshead in fair numbers, a kind of fish which they report had not been seen in the Sangamon before. This suggestion that the sheepshead is a newcomer is substantiated by our findings. We took ten specimens in the Sangamon within the county in 1928. Earlier collections by the Survey did not take the sheepshead from the Sangamon, either in this county or any place else along its entire length, although this species was taken in the Illinois River and in several other streams in the state. The specimens taken or seen in 1928 all weighed between 3 and 6 ounces—the same size, incidentally, at which the sheepshead have been observed in thousands in May below dams on the Rock River and below the head-gates of the Illinois-Mississippi Canal Feeder, attempting to go upstream. The fact that the collections and reports of sheepshead in the Sangamon in 1928 and 1929 are scattered over fifty miles or more of stream, argues that these fishes have migrated upstream from some point further down, rather than that they have been planted locally in many places.

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leafed through the book together, meanwhile checking the fishes they had seen in the vicinity against my species list for the river. I pointed to the picture of the sculpin (**Cottus ictalops**) and remarked that they probably had not seen it because we had not taken it in our extensive program of collecting in the basin. The older brother spoke up and said, "Yes, that's a **doogy pawl**. I call it that because it looks like a fish by that name I used to catch when I was a boy in Scotland." He went on to relate that for many years they had made a business of catching minnows for the bait market in the small streams about Rockford and that there used to be one place, and one place only, where they found the sculpin. This place was in a small stream tributary to Sarver Creek, about seven miles northwest of Rockford. They had first noticed it there some 15 or 20 years previously, and they had not been to the place for the past several years. The younger brother agreed to go with us next day and point out the place. When we arrived, there was a rocky riffle about 10 feet long in a tiny stream in a pasture. We set our minnow net below the riffle, rolled some of the rocks over, and lifted out 3 or 4 sculpins. Then we seined just above the riffle, but got none. We seined below the riffle and took five or six more sculpins. A few yards further down we took none. Then we went on and seined over several hundred yards but found none. Persistently we seined in the vicinity of every bridge over this whole tiny stream system, but no sculpins. For several weeks as we worked over the small streams of that part of the Rock River basin, we tried every likely riffle, many of which were identical with the sculpin riffle, but nowhere did we find another sculpin. When our sculpins were compared with others of the same species collected in Indiana, they were found to differ in several minor details of body contour and minute structure. While the sculpin is in a different family of fishes from the darters, it is of about the same size and in point of shape and habit can best be described as an exaggerated darter.

There is another kind of migration that applies to all our larger fishes in Illinois streams and probably also to smaller kinds. In spring, summer, and early autumn the larger fishes are found in all parts of the larger streams; some are in fast water, some in smoothly flowing reaches, some hiding among brush and vegetation, and some in the deep pools of quiet water. As the water becomes cold with the approach of winter, these fishes become sluggish and stop feeding, then retreat downstream and join the fishes of the deep pools. In spring when the ice is gone and the water is warmer, they ascend the stream and begin feeding. Our investigations on Rock River have shown that the order in which the different fishes come into the quiet pools and eddies is quite definite and that the order in which they go out is the reverse of the order in which they come in. Furthermore, those that come in first are generally sluggish-water fishes; next are those of moderate current; and last are those of the swift waters, such as the red-horses and the common sucker. In Rock River the wall-eyed pike may or may not retreat from the fast water during winter. This pike is very active in its movements all winter and feeds voraciously and is taken on the hook in swift water every month in the year. The fishes soonest benumbed are those that live in summer in the deep pools, such as the blunt-nosed river carp, the sheepshead, the buffalo fishes, the quillback, the carp, and the gizzard shad. The last-named fish seems particularly susceptible to cold, being seriously winter-killed.

Fishes in the headwaters of the Salt Fork are but two or three miles overland from fishes in the headwaters of the Sangamon, but as a fish travels they are more than 1,200 miles apart. Such long distances, doubtlessly, are traversed in a reasonable period of years by the larger, abler, and habitually swimming species. The uniformity in contour, color pattern, and morphological detail within such strong swimming species as the suckers and the larger sunfishes bears witness to frequent interbreeding within the species and lack of isolation. On the other hand, minnows, darters, and small species of other groups with feeble swimming powers and with a tendency to spend most of their time in restricted habitats, such as under and around stones, among vegetation or other cover, small eddies below riffles, etc., may be effectively isolated for very long periods of time, especially if they are in different streams and separated by many miles of water. Even in the same stream their distribution is "spotty" because they are sedentary or are adapted to limited kinds of habitat.

It may be possible, however, for some fishes to pass from one basin to another, in such flat country as we have in Champaign County, during prolonged periods of extremely wet weather. This is indicated in the state distribution of the silver-mouthed minnow (*Ericymba buccata*). That this minnow should pass from one basin to another is not at all surprising, since we have already shown that it is an extreme headwater species and will even ascend tile drains. The present data indicate that interbasin passing does not occur unless it be among the extreme headwater species. Among the isolated species in general, there is no evidence of any extended migration during the spawning period.

Among families of small fishes, ichthyologists have found local races and varieties to be the rule. Among freshwater fishes commonly inhabiting headwaters and other out-of-the-way "niches" in the environment, inordinately large numbers of species and varieties of minnows and darters are recognized. While our Champaign County collections have not yet been thoroughly studied with this in view, racial differences in morphological detail have been found, as will be fully reported in a later paper. Several of these differences may be mentioned here: (1) The fan-tail darter in Champaign County is restricted to the Sangamon, Salt Fork, and Middle Fork basins. Sixteen specimens from the Sangamon and its tributaries each had 8 dorsal spines. Of 7 specimens from the East Branch of the Salt Fork, four had 8 spines and three had 7 spines. Nine specimens from the Middle Fork and its tributaries each had 7 spines. (2) The log perch taken in the Kaskaskia Basin have a color pattern distinctly different from those taken from the Middle Fork Basin. (3) The orange-spotted sunfishes of the Sangamon have a body shape which differs markedly from those of the Salt Fork. (4) Within certain small species there seem to be consistent differences in the numbers of vertebrae between different stream systems.

A casual survey of the literature on geographical races among motile animals gives the impression that isolation is a more effective cause of racial differences within a species than is a difference in environment to which an animal may respond directly in one generation or be gradually adapted over many generations. If this be true, the explanation of geographical races is to be sought in terms of the properties of the germplasm and of the growth of populations rather than in terms of the response of the organism to the environment. Every species that has been studied genetically has shown heritable variations of greater or less degree. Furthermore, these heritable variations are continually arising *de novo* by changes in the germplasm due to causes entirely unrelated, as far as is known, to ordinary variations in the physical environment. While most of these heritable variations are disadvantageous to the animal and are rapidly eliminated, many of them are of indifferent selective value and may persist. Yet it is a significant fact that no heritable variations have been found which are more viable and can crowd out the "wild type." This superlative position of the "wild type" suggests that it represents the highest possible combination of hereditary factors affecting viability, and if so, variations in viability can occur only in the downward direction.

It is common experience that a population of a species is at all times heterogeneous, its degree of heterogeneity being dependent primarily on the rate of origin of variations *de novo* as compared with the rate of their elimination due to selectivity and the degree of inbreeding. The degree of inbreeding is important because it is a common fact of all population studies that the population of a species within an isolated area at any one time is not descended from the entire population of that species in that area, let us say several generations earlier, but from a fraction of it. If, in any generation, by chance, the parents of the next generation are all homogeneous for some indifferently selective, heritable variation which has arisen *de novo*, then the character of the whole population will have been changed without regard to the selective value of the variations or environmental differences. Since these heritable changes arising *de novo* are fixed in populations by *chance*, the probability is infinitely small that the same changes will arise and be fixed in isolated populations. Hence, as long as populations are isolated, heritable differences from the original condition, and from each other, will accumulate. If, however, interbreeding is occasionally possible between partially isolated populations, their differences will tend to be ironed out, likewise, *by chance*.

Of the 74 species taken within the county, there are 17 which have been collected in sufficient numbers to avoid errors due to random sampling and which are absent from one or more of the six stream systems. Furthermore, these 17 kinds include *only* those species whose *preferred habitat and stream size* are known *to occur generally* in the streams from which they are absent. These species are listed below, together with the stream systems in which they have been taken.

Species	*Stream Systems*
Pimephales promelas	Sangamon
Hybognathus nuchalis	Kaskaskia
Notropis gilberti	Sangamon
Notropis atherinoides var	Middle Fork
Notropis illecebrosus	Middle Fork
Hybopsis amblops	Middle Fork, Salt Fork, Embarrass
Cliola vigilax	Sangamon, Salt Fork
Schilbeodes gyrinus	Salt Fork
Schilbeodes miurus	Salt Fork
Lepomis humilis	Sangamon, Middle Fork, Salt Fork, Embarrass
Aphredoderus sayanus	Sangamon, Embarrass, Kaskaskia
Labidesthes sicculus	Salt Fork
Etheostoma coeruleum	All but the Kaskaskia
Etheostoma flabellare	Sangamon, Middle Fork, Salt Fork
Etheostoma zonale	Sangamon
Diplesion blennioides	Middle Fork, Salt Fork, Embarrass
Ammocrypta pellucida	Middle Fork

As these fishes are examined to see what they have in common, we find, first, that they are all small, the largest specimen among them being a *Hybognathus nuchalis* 3¼ inches long. More than half of them are clearly sedentary in habit and spend most of their time hiding. All of them are specialized physiologically, since they are restricted to special kinds of habitats which are usually of discontinuous distribution. Our findings on these fishes correspond, both in general and in detail, with the data on their distribution in the state and in the county as given by Forbes and Richardson in "The Fishes of Illinois," and with Hankinson's data in the "Distribution of Fish in the Streams about Charleston, Illinois."[12]

12. Loc. cit.

Since the streams of Champaign County are so similar and offer the same variety of habitats, it may be assumed that the absence of one of these species from a stream system is due to one of two things: either that it may never have extended its range into that stream, or that it may have been there formerly but is now absent as a result of some catastrophe which wiped it out. Both of these explanations are necessary to account for all the data. The first applies to *Diplesion blennioides, Notropis illecebrosus,* and *Schilbeodes miurus,* which are strictly limited to the Wabash drainage in Illinois, and *Etheostoma zonale, Notropis gilberti,* and *Pimephales promelas,* which are limited to the Mississippi drainage. The second explanation covers certain changes in the distribution of individual species in the county during the period between the earlier collections of the Survey and the present ones—changes which indicate catastrophes of one kind or another: disease, an exceptionally cold winter or hot summer, pollution, predators, *etc.*

The most pronounced case of *increase* in abundance is found in the horned dace (*Semotilus atromaculatus*) in the Salt Fork. In the period 1882 to 1901 not a single specimen of this species was taken in the 25 collections of fishes made in this stream and its tributaries, but in 1928 it occurred in 48 out of our 52 collections in the same areas, which thus contributed 1,547 of the total of 2,873 specimens taken this year in the whole county. At the time of the earlier collections small hatchery ponds were maintained in Urbana by the Illinois Fish Commission, and they were stocked with a variety of fishes from various parts of the state. A collection of fishes made in this hatchery by Professor Frank Smith and Mr. R. W. Mills in November, 1898, included among a miscellany of other fishes 3 specimens of the horned dace between 4 and 7 inches long. It seems very likely that individuals escaping or being released from this hatchery into the West Branch served as seed for the stocking of the entire Salt Fork basin, which formerly did not contain this species. The suitability of the Salt Fork as an environment for horned dace is witnessed by their greater abundance in this stream at present than in other parts of the county. It would have been most interesting to follow their spread and multiplication in this system, to see how closely their numbers conformed to the logistic curve of population growth; but without such evidence the length of time involved is entirely problematical.

Another case of remarkable increase is that of the silver-mouthed minnow (*Ericymba buccata*). No minnows of this species were taken in the 8 collections made in May, 1901, in the Sangamon in Champaign County, and only one was taken then in Piatt County; but during last year silver-mouthed minnows have been found in 26 of the 29 collections from that stream, which has thus furnished 1,547 of the 3,519 specimens taken from all the streams of the county.

Evidence indicating the recent appearance of the sheepshead in the upper Sangamon has already been presented.

These cases indicate clearly that certain fishes can fare well in places other than their original habitats. With modern transportation facilities and fishes being carted hundreds of miles alive, both for stocking purposes and for bait, it seems certain that within a comparatively short period evidence concerning the original distribution of fishes, as well as racial distinctions, will be obliterated.

There is evidence that the small-mouth black bass is more abundant in the Sangamon now than formerly. None of this species were taken in the 8 collections made in 1901, but 12 of the 29 collections made there in 1928 contained the small-mouth, and these 12 collections furnished 35 of the 44 specimens taken this year in the whole county. It also seems to have increased in the Middle Fork in the same period; for none were taken in the 3 earlier channel collections while 9 were taken in the 4 recent channel collections.

There is some evidence of *decreases* in the abundance of several species. The silvery minnow (*Hybognathus nuchalis*) was taken in 2 out of the 8 former collections in the Sangamon, but not at all in the 29 recent collections in the same stream. The spotted sucker (*Minytrema melanops*) was formerly taken in both the Sangamon and the Middle Fork, but not at all in 1928. It is possible that the increase in small-mouth black bass in these two streams may have had something to do with the disappearance of the above fishes.

A number of species formerly present in the stretch of the Salt Fork between Urbana and the Homer Dam are now absent, obviously because they are not tolerant to pollution.

A few other species in other streams of the county may have changed their range or abundance, or both, since 1901, but the earlier collections were not extensive enough to justify statistical comparisons except in the Salt Fork and the Sangamon.

The above observations on changes in distribution do not substantiate the view that the fish life of a stream is a highly integrated whole to which nothing can be added or subtracted without upsetting the "balance."

Association of Species

Most instances of the association of different species of fishes are explained satisfactorily by similar environmental preferences. This phase of the ecology of Illinois fishes has been treated very completely and critically by Professor Forbes in "Fresh-water Fishes and Their Ecology," and "On the Local Distribution of Certain Illinois Fishes: an Essay in Statistical Ecology." In these papers he has presented coefficients of association of certain species with certain other species and with certain environmental characteristics. Tables of such coefficients for important food and game fishes and their associates can be put to good use in formulating principles for the efficient management of our waters and in making recommendations for planting important fishes in waters where they are not already present. In actual practice a body of water in which planting is to be done would be inspected as to its general features and the more abundant kinds of fishes noted. Desirable kinds of fishes not already present would be selected for successful planting from those showing high coefficients of association, elsewhere, with fishes already present and with the general features of the aquatic environment.

An instance of another order of association of species came to light in the course of the present study, a new order of association that is distinguished by its extreme exactness. It approaches the order of correlation to be expected between males and females of the same species and implies that at some stage in their life history the presence of both species is necessary for the maintenance of a large population of either.

This new kind of association was discovered in the relations of two large minnows: the horny head, *Hybopsis kentuckiensis;* and the shiner, *Notropis cornutus.* One or both of these minnows were taken in 55 of the 132 collections in the county, and all but two of these 55 collections were made in three river systems—the Sangamon, Kaskaskia, and Middle Fork—the two exceptions being in the Salt Fork basin. *Notropis cornutus* occurred in 54 of these 55 collections and *Hybopsis kentuckiensis* in 46 of them. To put it on the basis of number of individuals: 2,618 specimens of *Notropis cornutus* were taken in all, of which 2,590 were in the same collections with *Hybopsis kentuckiensis;* and of the 1,221 specimens of *Hybopsis kentuckiensis,* 1,217 were taken in collections with *Notropis cornutus.* The actual number of each of these species in each of the 55 collections in which one or both were taken during 1928 is shown in Table XII.

An inspection of the distribution maps of these two species indicates that they both are restricted to certain systems very much as the seventeen other species which have been described earlier in this paper as showing isolation. There are, however, several important points in which these two fishes do not conform with the characteristics of other species with a restricted distribution. All our other restricted fishes are small (not exceeding 3¼ inches in length in this area) and either sedentary in habit or restricted to certain limited types of environment, but these two are our largest minnows, specimens of both having been taken more than 6 inches in length. Furthermore, they are both strong swimmers and are not sedentary in any sense of the word. Neither are they restricted to any limited type of environment, both of them having been found in almost every type of stream environment in this area.

It is often mentioned in the literature that *Notropis cornutus* is a typical small-stream fish while *Hybopsis kentuckiensis* is more characteristically found in large rivers. This difference is not indicated by our Champaign County data. Following is a tabulation of the average numbers of these two species per 100 square yards of water area in streams whose sizes are expressed in square miles of drainage area:

	1	2	4	8	16	32	64	128	256	512
Notropis cornutus	10.0	25.0	88.8	64.3	132.6	141.0	31.7	35.8	10.8	
Hybopsis kentuckiensis	0	4.5	2.0	46.9	74.1	33.6	11.3	17.6	9.2	

The largest specimen of the shiner was taken in the same collection as the largest chub. There is, moreover, a general correspondence between the sizes of these two fishes in all our collections in the county.

The association of these two species is not obviously a predator-victim relationship, because studies of their stomach contents show them both to be omnivores, taking either plant or animal foods of a wide variety. For many years I have taken these two fishes in almost equal numbers on trout flies and a variety of other baits on the riffles of Wild Cat Creek near Lafayette, Indiana.

The degree of association of these two species in the state at large does not appear so exact as in Champaign County. One or both of them occurred in 203 of the 1,800 collections of fishes reported by Forbes and Richardson. *Notropis cornutus* occurred in 185, and *Hybopsis kentuckiensis* in 139, of those 203 collections. On the basis of numbers of individuals: 725 of the 855 specimens of *Hybopsis kentuckiensis* taken in the state were taken in the presence of *Notropis cornutus;*

Table XII. Numbers of *Hybopsis kentuckiensis* and *Notropis cornutus* and total of all fishes in Champaign County collections in which one or both of these species occur. Arranged in order of decreasing stream size within each stream system.

Hybopsis kentuckiensis	Notropis cornutus	Total of all fishes in collection
Sangamon River		
6	9	434
19	8	289
20	28	324
24	39	332
17	11	144
14	22	240
3	4	236
15	11	302
36	68	399
23	44	408
33	88	374
40	193	532
6	18	83
21	59	940
31	150	714
27	212	506
28	161	442
25	134	320
51	135	376
55	137	503
10	50	321
123	41	261
3	32	41
68	41	321
2	37	152
3	13	35
31	73	649
......	14	160
......	1	43
1	11	19

Hybopsis kentuckiensis	Notropis cornutus	Total of all fishes in collection
Kaskaskia River		
4	51	223
......	2	37
6	100	177
39	27	128
44	37	107
21	66	121
64	21	134
111	11	278
8	2	115
89	33	263
42	33	130
10	76	110
4	......	14
4	38	89
Middle Fork River		
13	43	615
6	31	321
11	35	152
7	35	420
......	2	137
3	110	368
......	4	182
......	3	546
......	2	174
Salt Fork River		
......	1	37
......	2	324

conversely, 2,184 of the 2,666 specimens of *Notropis cornutus* were taken with *Hybopsis kentuckiensis*. The lower incidence of these two species and the comparative smallness of the earlier collections would tend to lower the probability that specimens of both would be included in any given collection. However, the state-wide data does contain some evidence that one of these species, particularly *Notropis cornutus*, can occur in larger streams independent of the other.

The general distribution of *Notropis cornutus* is given by Jordan and Evermann[13] as,—"Entire region east of the Rocky Mountains excepting the South Atlantic States and Texas; *almost* everywhere the most abundant fish in small streams. Its variations are great, some of them appearing like distinct species." The general distribution of *Hybopsis kentuckiensis* is given as,—"Pennsylvania to Wyoming and Alabama, on both sides of the Alleghenies; everywhere abundant in the larger streams, seldom ascending small brooks; western specimens usually have the teeth in two rows. Variable."

Reports on the fishes of many other areas within the range of these species clearly indicate a correspondence of the detailed distribution of the chub with the shiner.

The explanation of why these two species show isolation in certain stream systems seems to be embodied in the nature of their association. It may be that, while they are necessary to each other's existence at least to attain abundance, the necessity of their association extends over only a part of their life history, so that they can move into other areas independently of each other. Whether or not they shall occupy the new area, may then depend on the small probability that they should both get there at the same time.

SUMMARY

Champaign County, which is nearly level upland plain, embraces the neighboring headwaters of six stream systems which diverge in various directions, sending their waters into the tributaries of the Wabash on the east and the Mississippi on the west.

Quantitative collections containing 28,905 fishes were made in 1928 from 132 localities on these streams, and with these were combined for study the product of 40 collections from this same area, made in the course of a general survey of the fishes of the State in the period 1882-1901. The identity of the specimens from all these collections has been determined, and the data of their distribution and abundance in the different seasons and in the several habitats of each stream have been organized to show factors affecting distribution. These two series of collections, together with a few miscellaneous collections and reports from Champaign County, include representatives of 74 species.

13. Jordan, David Starr, and Evermann, Barton Warren: "The Fishes of North and Middle America." Bulletin 47, Smithsonian Institution, U. S. National Museum. 1896.

From the data of 1928 it appeared that the streams of the county contained an average of three fishes per square yard of water, equivalent to 15,000 fishes per acre, with a total weight per acre of about 150 pounds.

Data of temperatures and rainfall are given for 1928, when the collections were made, and for the 26 years during which accurate observations have been recorded.

Dredging of the streams for farm drainage is common, and its effect on the fishes are temporarily serious; but erosion and the growth of water plants and of stream-side shrubs and trees presently reproduce original conditions, so that the general effect of dredging is not important.

The coarse aquatic plants of the waters of the county are listed with statements as to the situations in which they occur.

Nine principal classes of habitats in Champaign County streams are recognized, and the species of fishes most characteristic of each are listed.

The number of fishes per unit area varies from seven per square yard in extreme headwaters down to two per square yard in the larger streams, but this decrease in number of fishes downstream is more than counterbalanced by an increase in the average size of the individual fishes.

In comparing the range of stream sizes which different species inhabit, it was found most satisfactory to throw the data on drainage areas into size classes which increase as a geometrical progression, each class being made twice the preceding class; for the numbers of fishes per unit area and the numbers of species per collection, when plotted against stream sizes on this scale, give curves that approximate straight lines—a good empirical reason for assuming that this is a correct method of comparison.

Some species which reach their greatest abundance at certain points in a stream also reach their greatest abundance in other streams at points with the same drainage area, without reference to distance from source or mouth.

Some species are sharply limited to a certain stream size, while others are more generally distributed but fluctuate about a certain stream size as a mode.

Although the young and adults of most species reach their greatest abundance in streams of the same size, the young of certain species of suckers regularly occur in smaller streams than do adults of the same species.

Fishes of the extreme headwaters are the hardiest, most tolerant of pollution, and most nearly omnivorous.

Correlation between unusual fertility of soil and abundance, rate of growth, and adult size of fishes is illustrated by an extraordinarily productive tract drained by Spoon River which yielded twice as many fishes to a given area and four to five times as many pounds of fish as the average for the county.

The effects of pollution are illustrated by an extreme scarcity of fishes—as for example, downstream from Champaign and Urbana, notwithstanding the operation there of a modern sewage disposal plant above which there were thirty times as many fishes per unit area and four times as many kinds as below. (See footnote 10, page 54.)

There are distinguished three types of morphological adaptation of fishes to the size of streams and velocity of their flow.

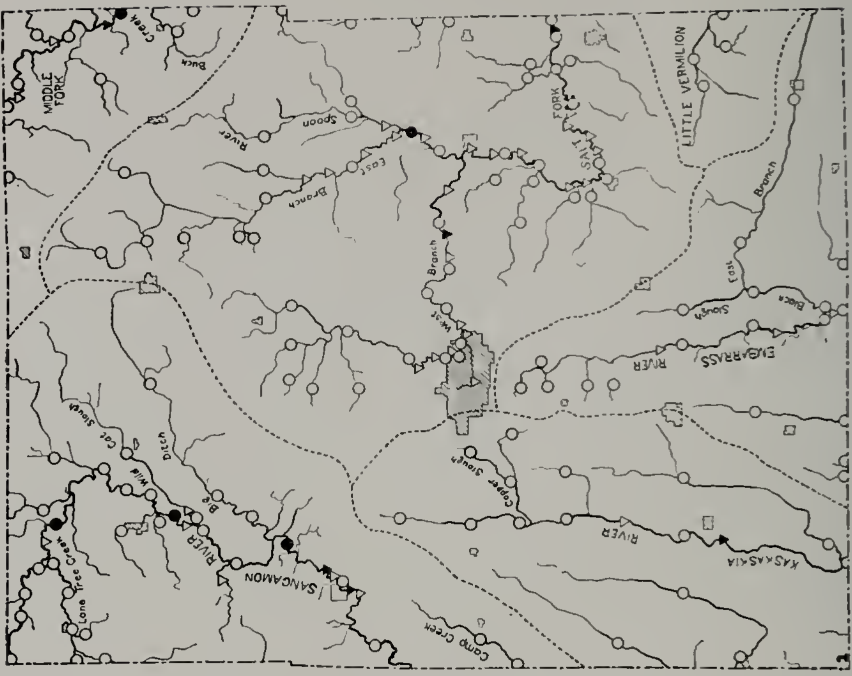
Notwithstanding the close neighborhood of the headwaters of the different stream systems and the similarity of their habitats and of their drainage basins, the local distribution of their species is so restricted that 17 species are wanting in from one to five of the six stream systems of the county; but examples are given of the ability of species thus isolated to survive and multiply in other waters if they gain access to them.

Attention is called to the indispensable importance of a knowledge of the natural limitations of the distribution and survival of economic species in different habitats, without which wasteful efforts will be made to introduce desirable species where they cannot thrive.

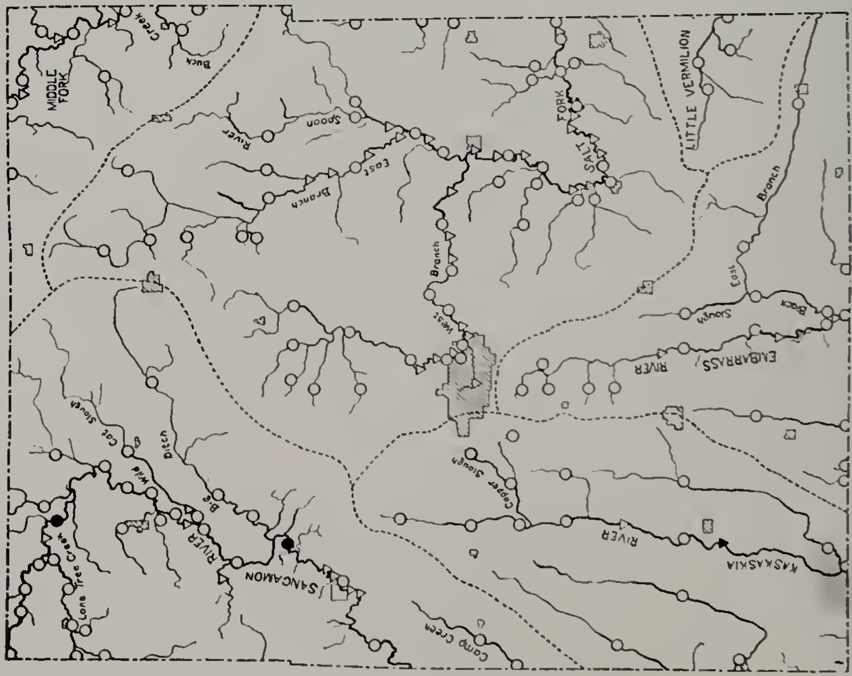
Two species, *Hybopsis kentuckiensis* and *Notropis cornutus*, exhibited an extraordinary and unexplained association, being found together in 99 per cent of the collections in which either one of them occurred.

DISTRIBUTION MAPS

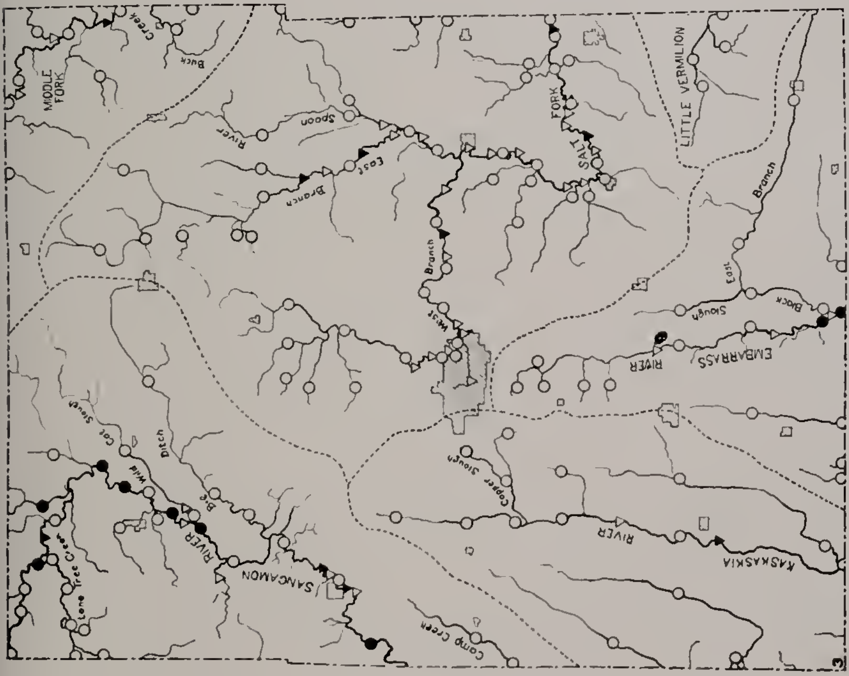
On the following pages distribution maps are shown for all species which were represented by ten or more specimens in the collections of 1928. Circles indicate places where collections were made in 1928, and triangles where collections were made in the period 1882-1901. The occurrence of each species is indicated by the use of these symbols in solid black. (For index, see p. 99.)



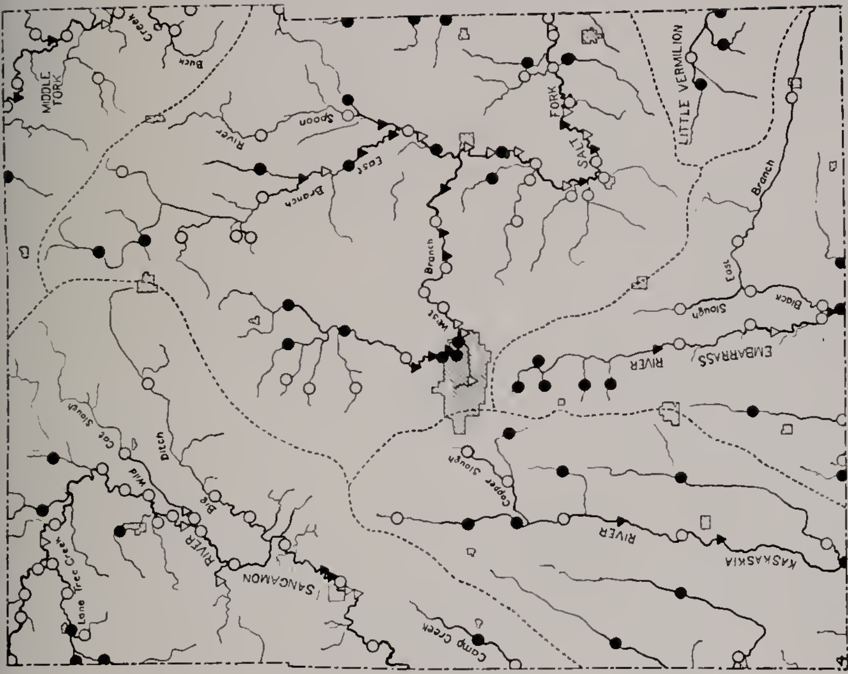
Map 2. Distribution of *Carpiodes difformis*—Blunt-nosed river carp.



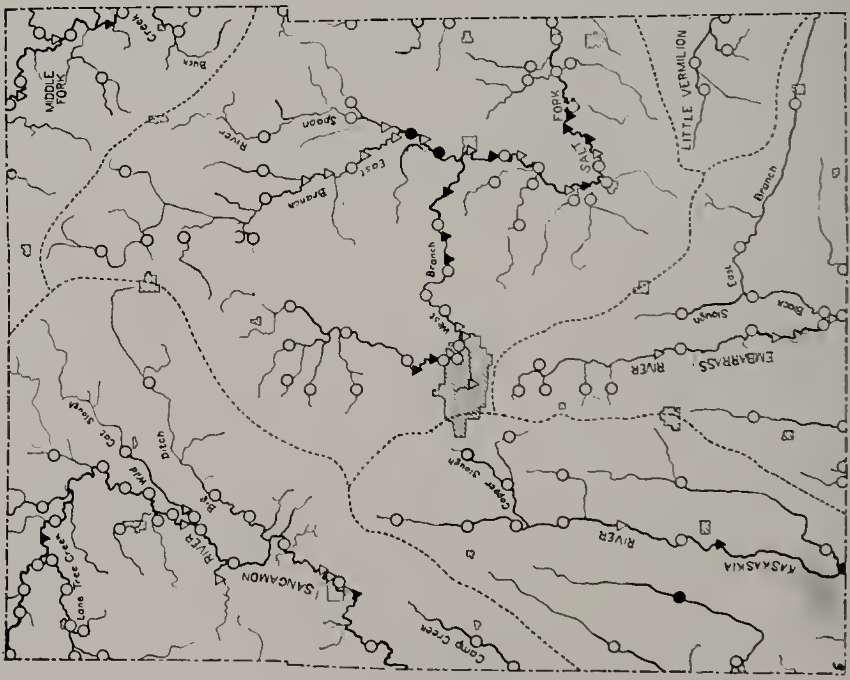
Map 1. Distribution of *Dorosoma cepedianum*—Gizzard-shad.



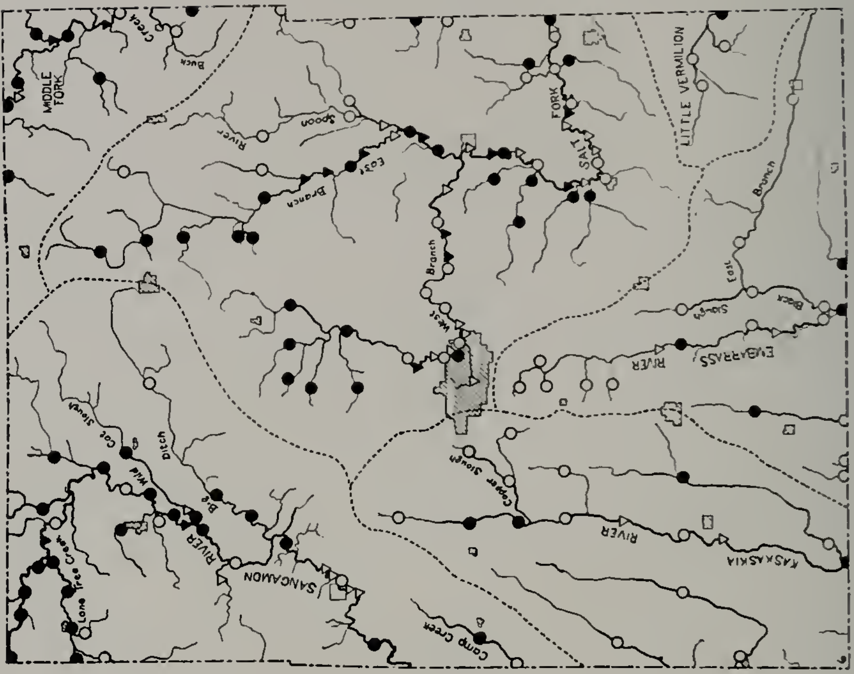
Map 3. Distribution of *Carpiodes velifer*—Quillback.



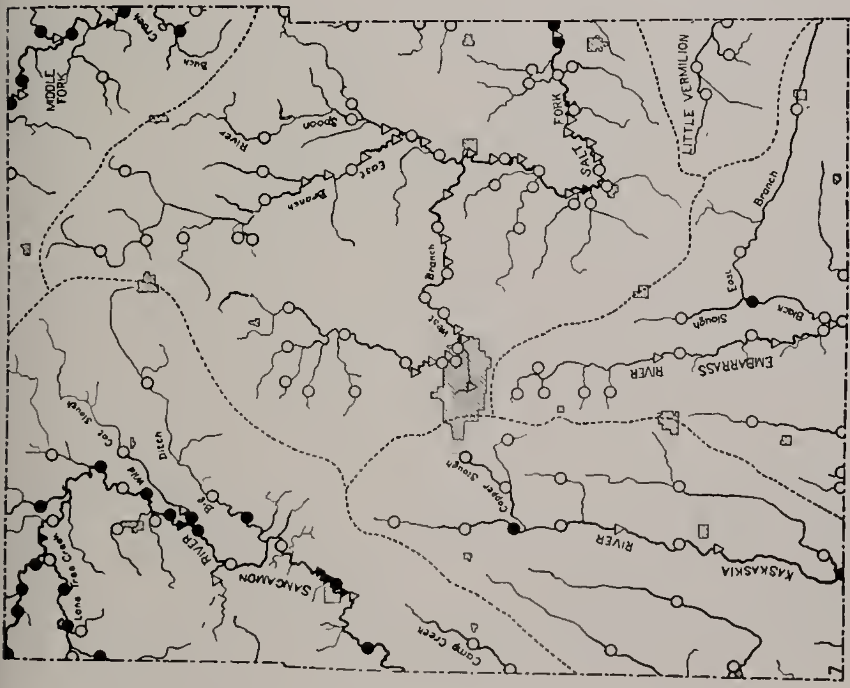
Map 4. Distribution of *Erimyzon sucetta oblongus*—Chub-sucker.



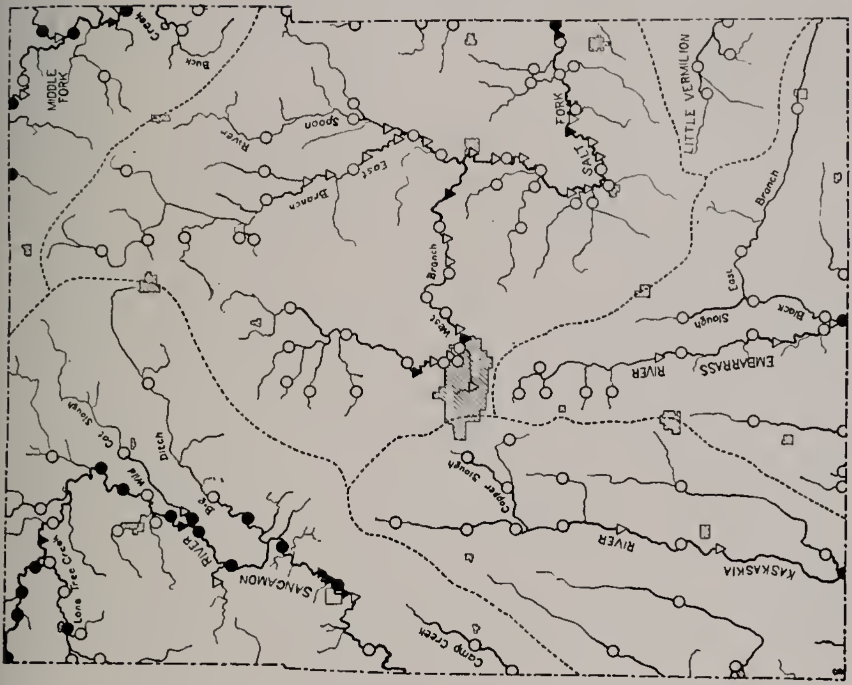
Map 5. Distribution of *Minytrema melanops*—Spotted sucker.



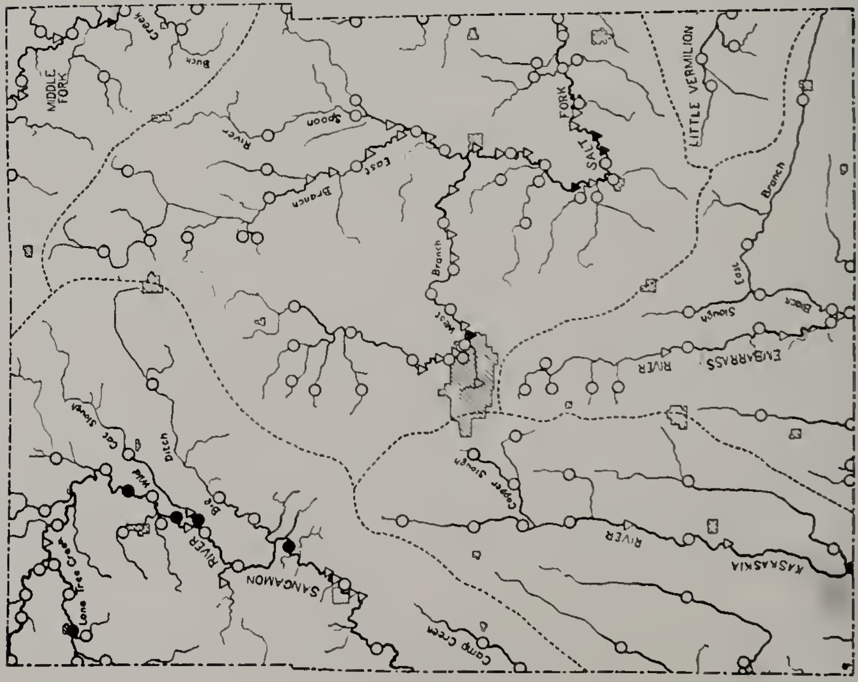
Map 6. Distribution of *Catostomus commersonii*—Common sucker.



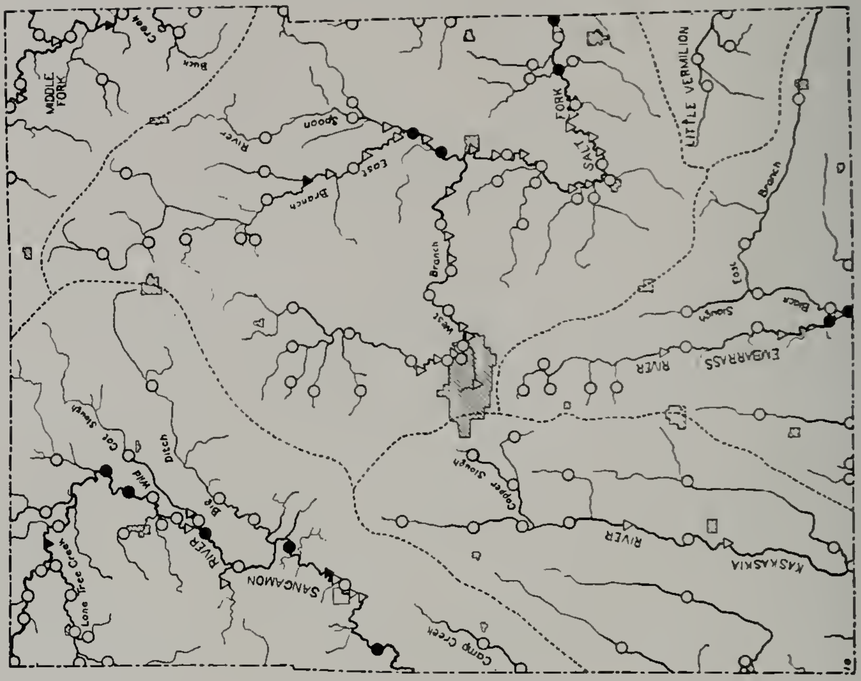
Map 7. Distribution of *Catostomus nigricans*—Hogsucker.



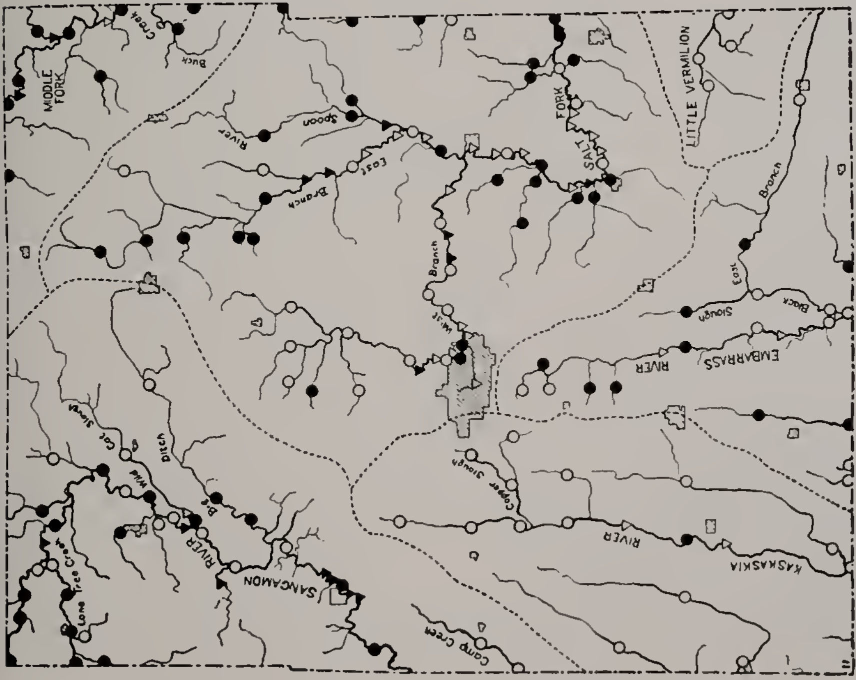
Map 8. Distribution of *Moxostoma aureolum*—Common red-horse.



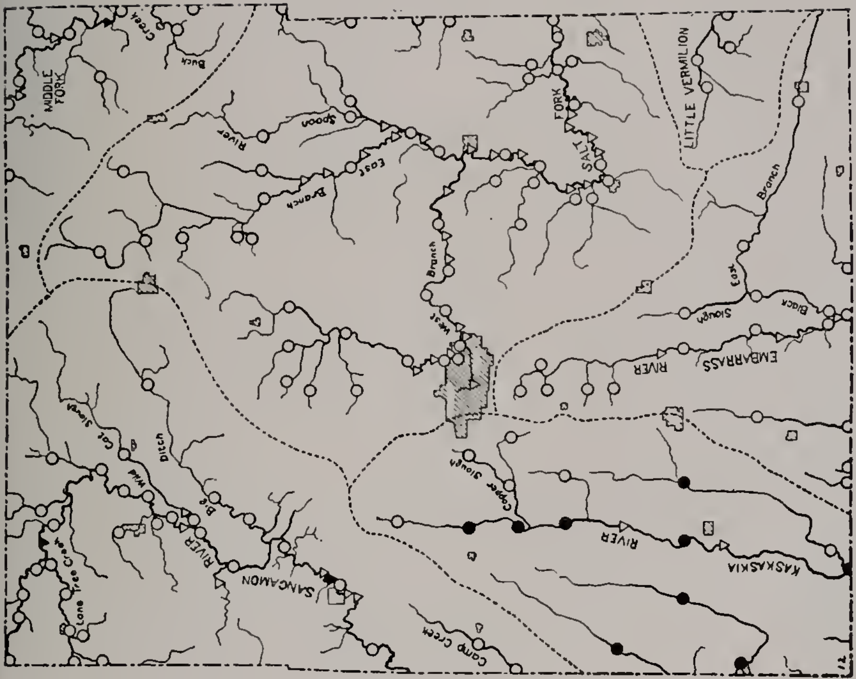
Map 9. Distribution of *Moxostoma breviceps*—Short-headed red-horse.



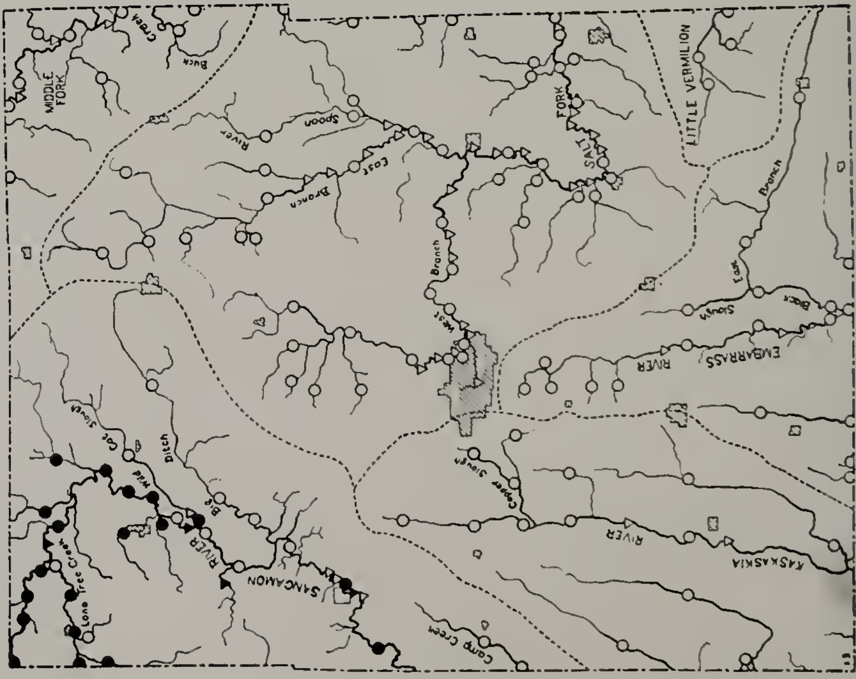
Map 10. Distribution of *Cyprinus carpio*—Carp.



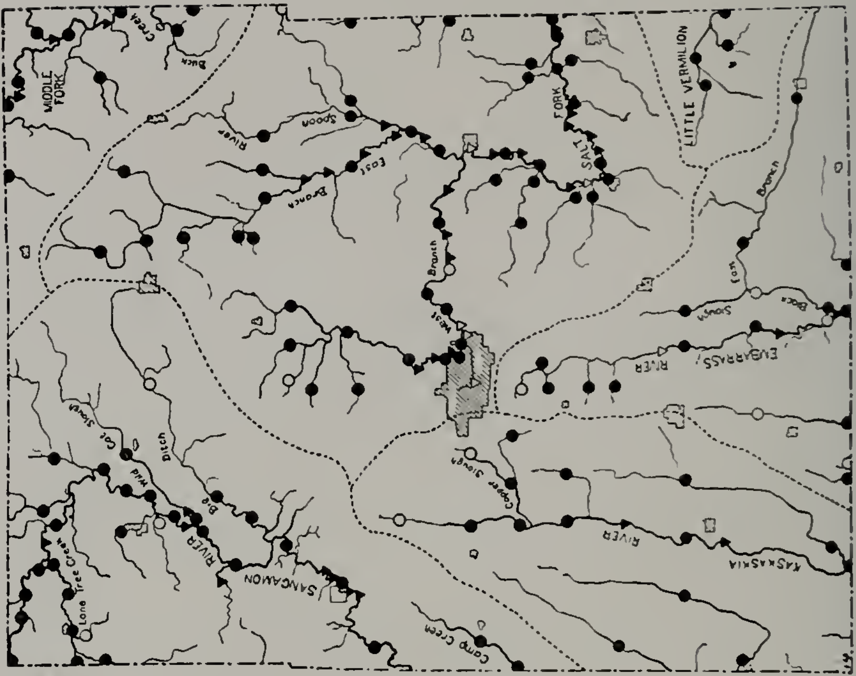
Map 11. Distribution of *Campostoma anomalum*—Dough-belly.



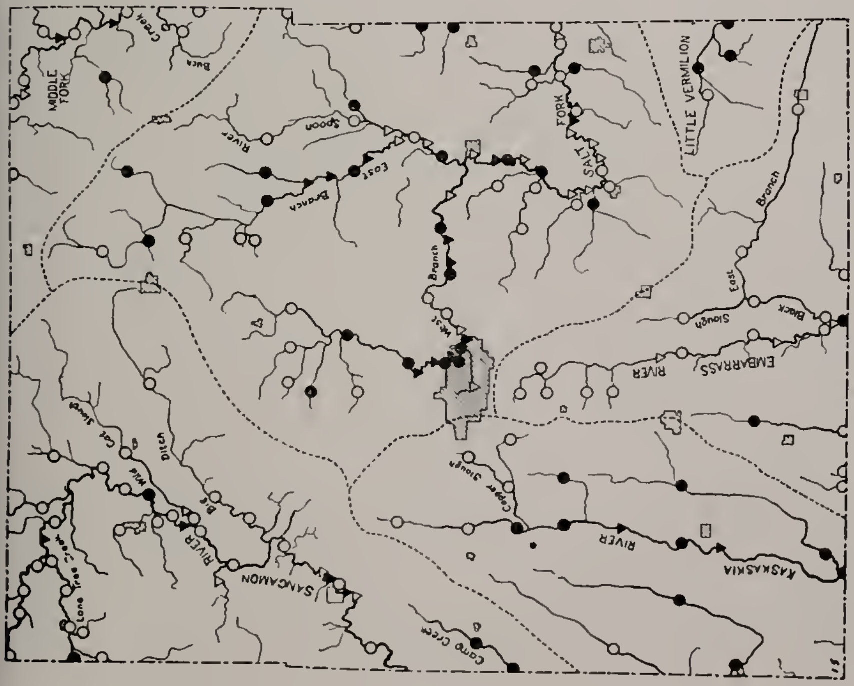
Map 12. Distribution of *Hybognathus nuchalis*—Silvery minnow.



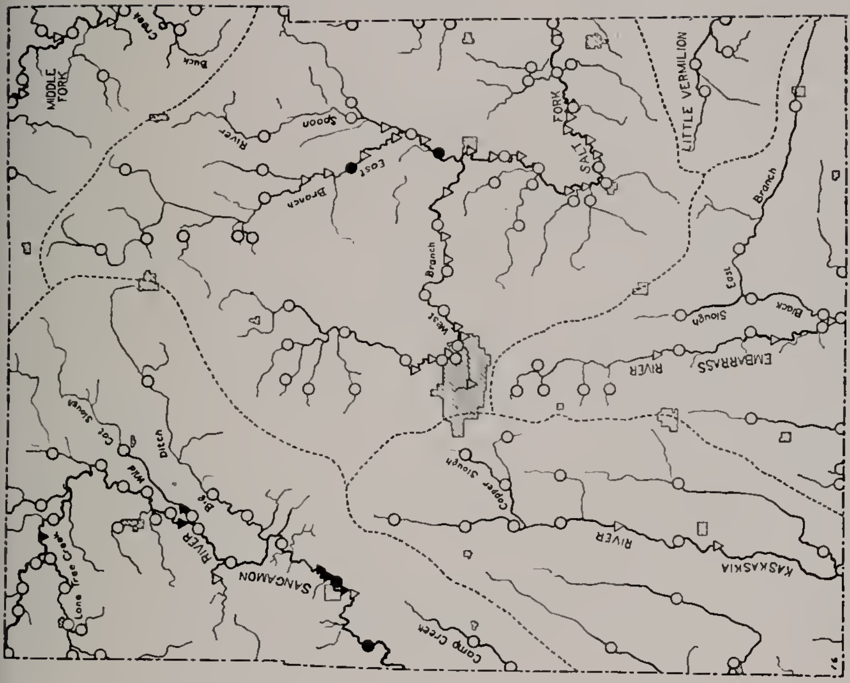
Map 13. Distribution of *Pimephales promelas*—Fathead minnow.



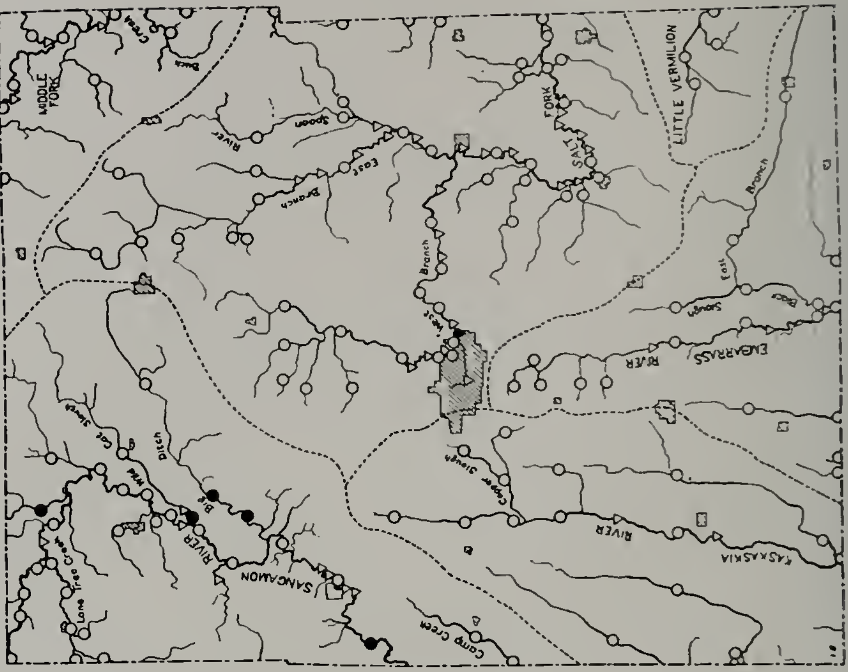
Map 14. Distribution of *Pimephales notatus*—Blunt-nosed minnow.



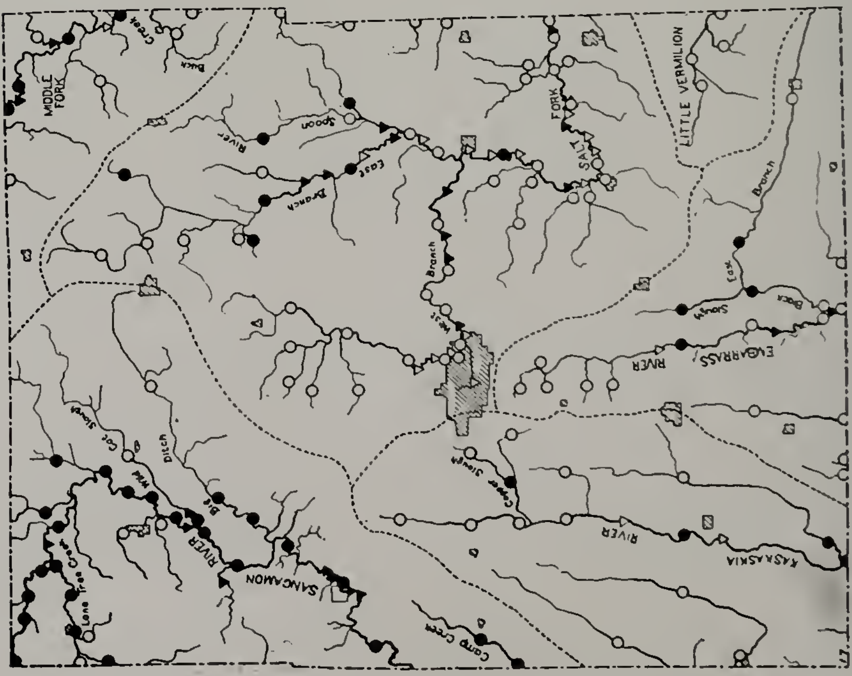
Map 15. Distribution of *Abramis crysoleucas*—Golden shiner.



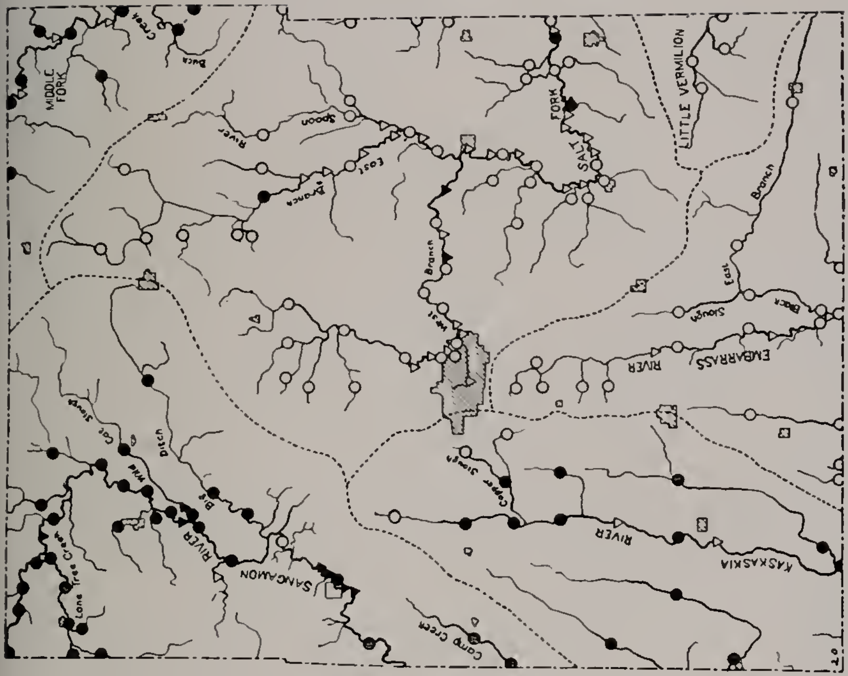
Map 16. Distribution of *Cliola vigilax*—Bullhead minnow.



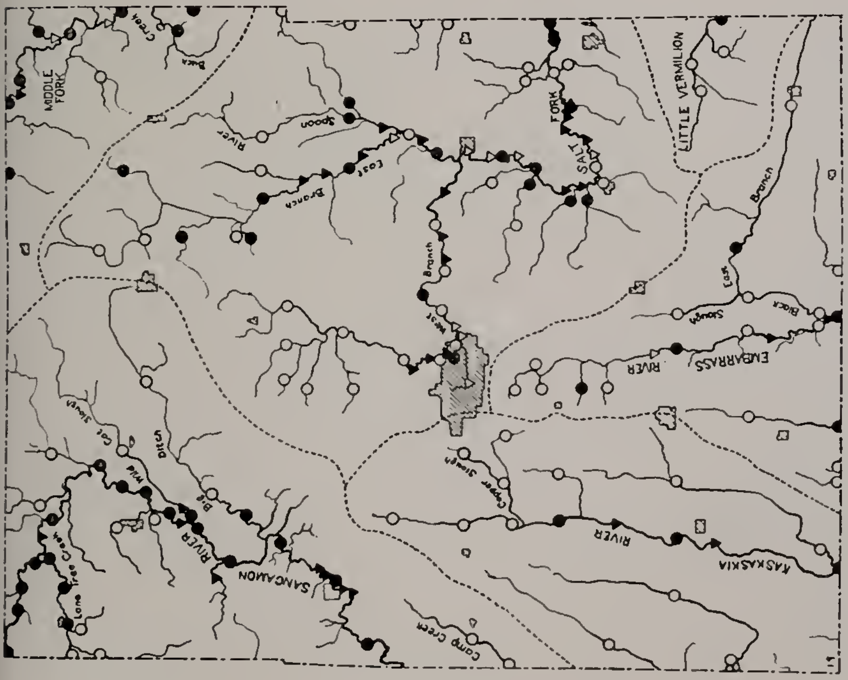
Map 18. Distribution of *Notropis gilberti*—Gilbert's minnow.



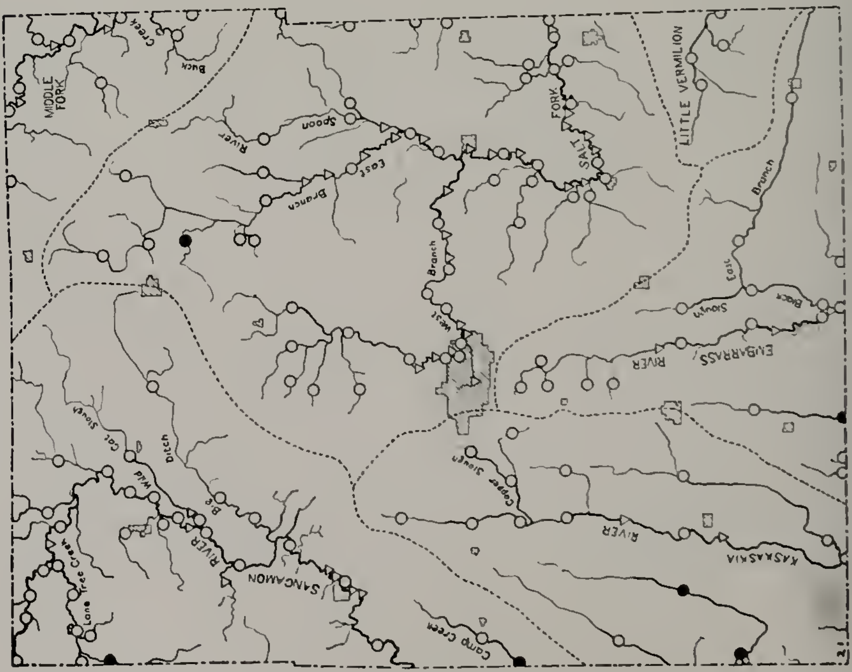
Map 17. Distribution of *Notropis blennius*—Straw-colored minnow.



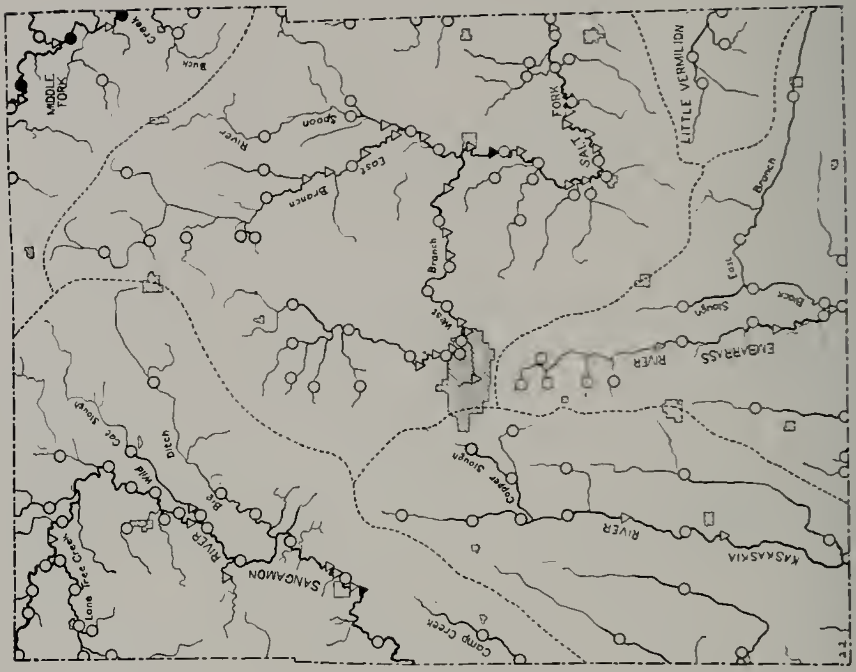
Map 20. Distribution of *Notropis cornutus*—Common shiner.



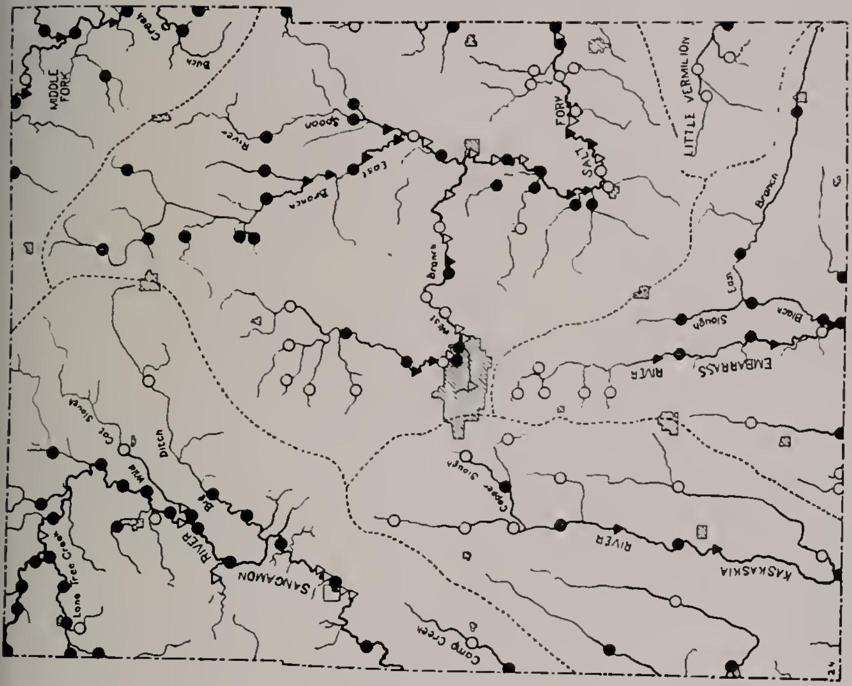
Map 19. Distribution of *Notropis whipplii*—Steel-colored minnow.



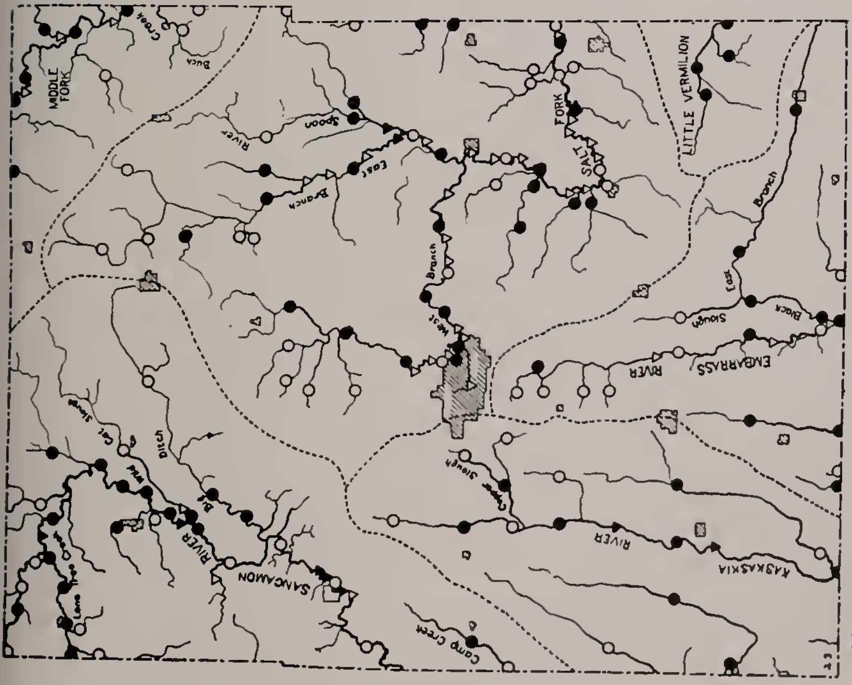
Map 21. Distribution of *Notropis pilsbryi*—Pilsbry's minnow.



Map 22. Distribution of *Notropis atherinoides*—Shiner.



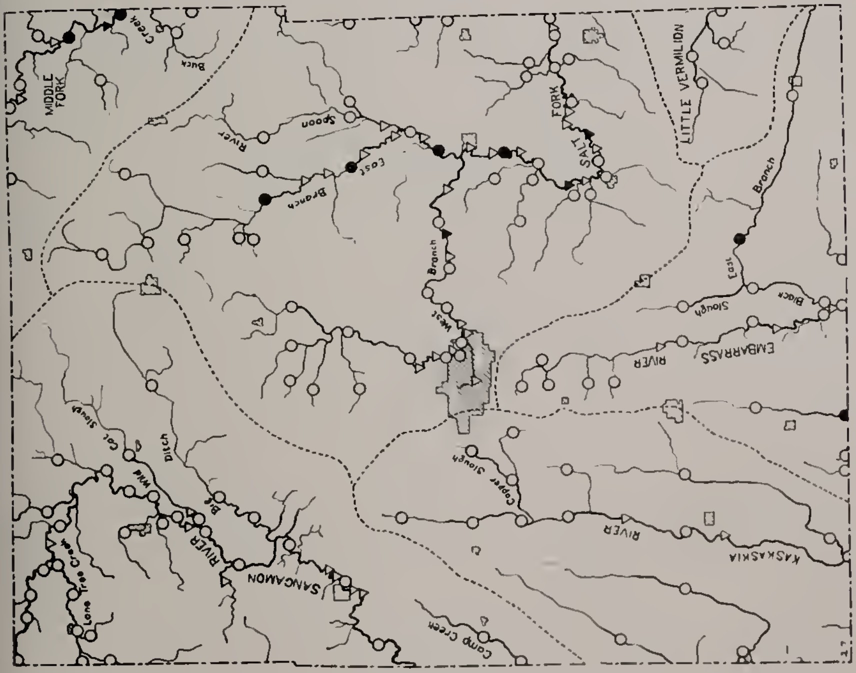
Map 24. Distribution of *Ericymba buccata*—Silver-mouthed minnow.



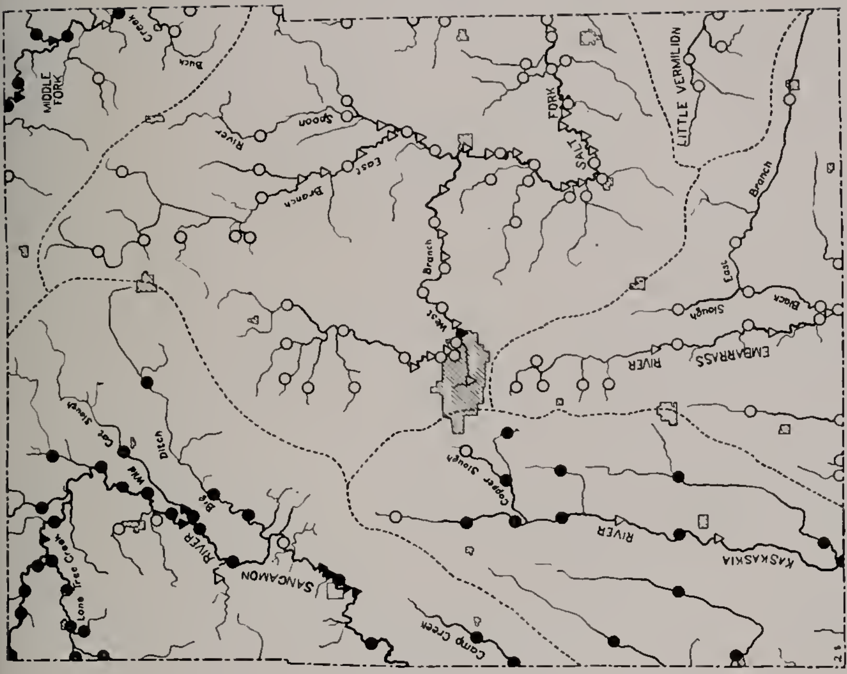
Map 23. Distribution of *Notropis umbratilis atripes*—Blackfin minnow.

Map 25. Distribution of *Phenacobius mirabilis*—Sucker-mouthed minnow.

Map 26. Distribution of *Semotilus atromaculatus*—Horned dace.

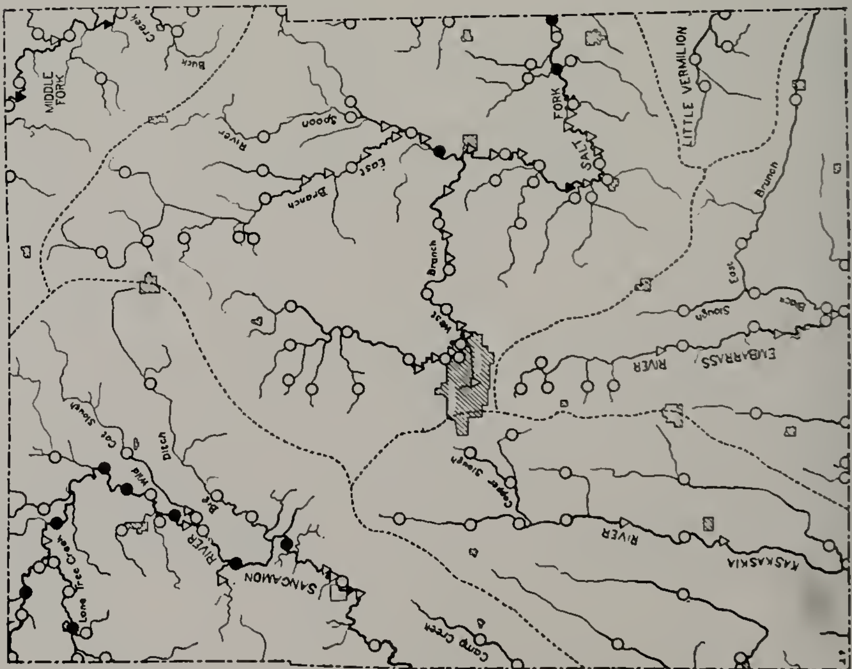


Map 27. Distribution of *Hybopsis amblops*—Big-eyed chub.

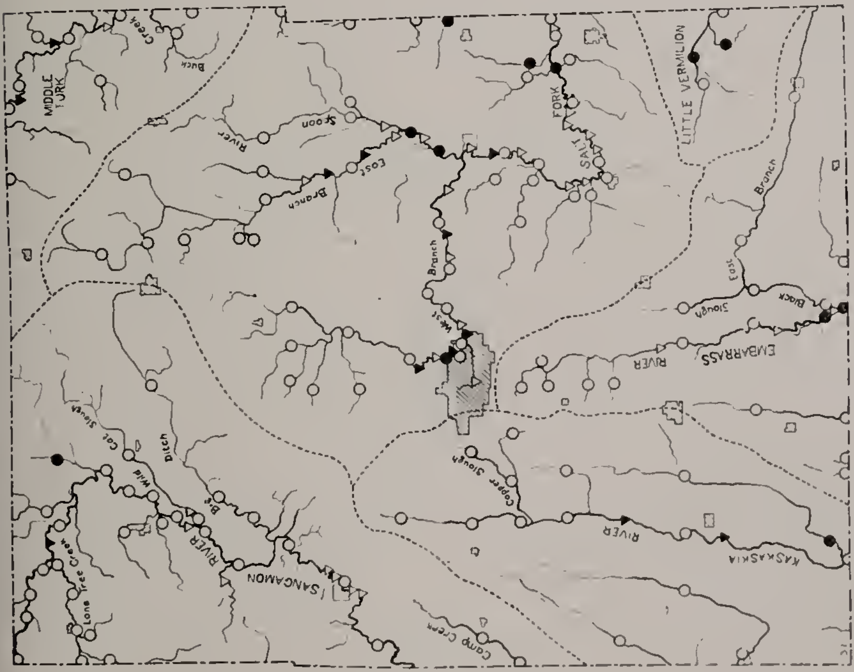


Map 28. Distribution of *Hybopsis kentuckiensis*—Horny-head.

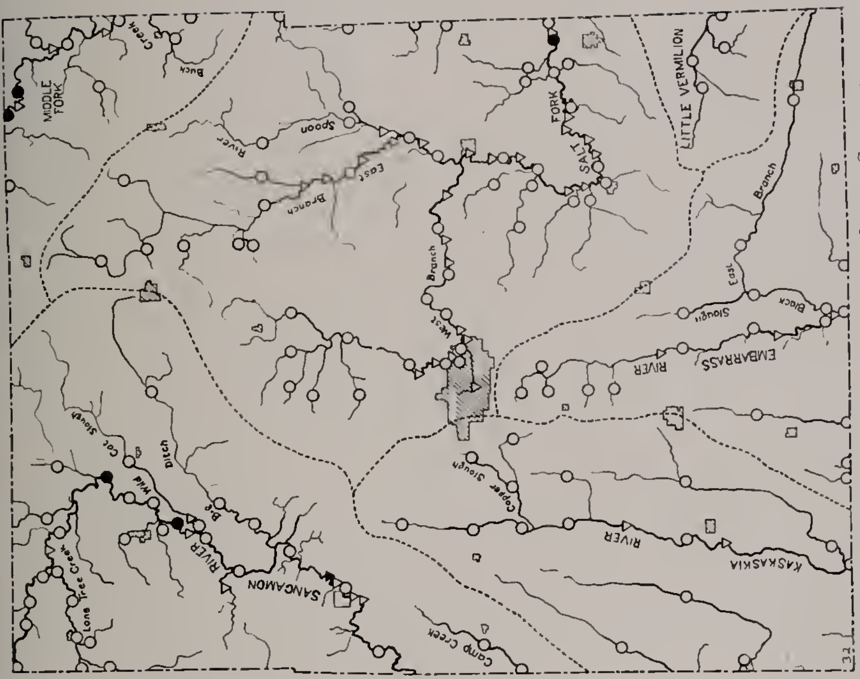
Map 30. Distribution of *Ameiurus natalis*—Yellow bullhead.



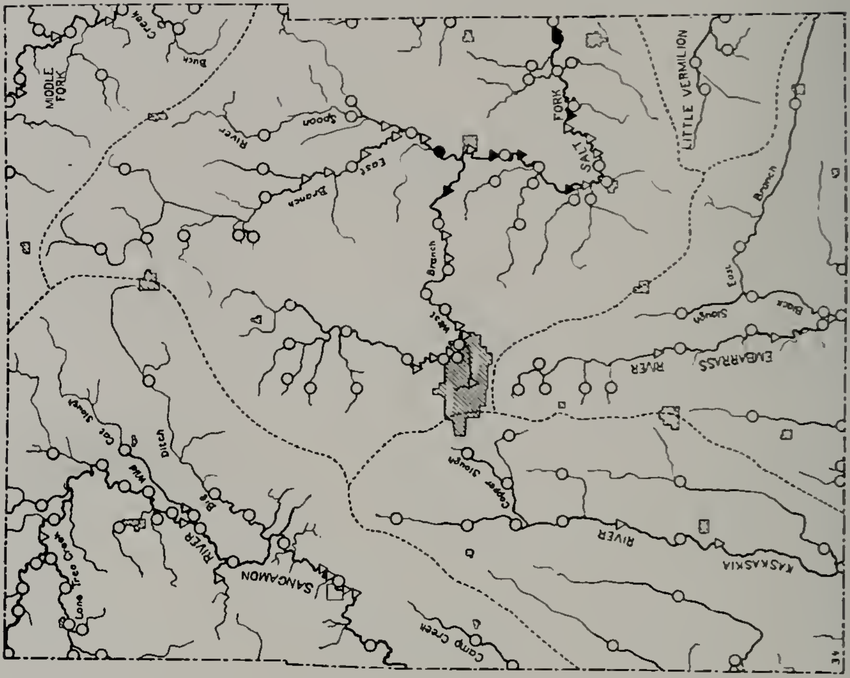
Map 29. Distribution of *Ictalurus punctatus*—Channel-cat.



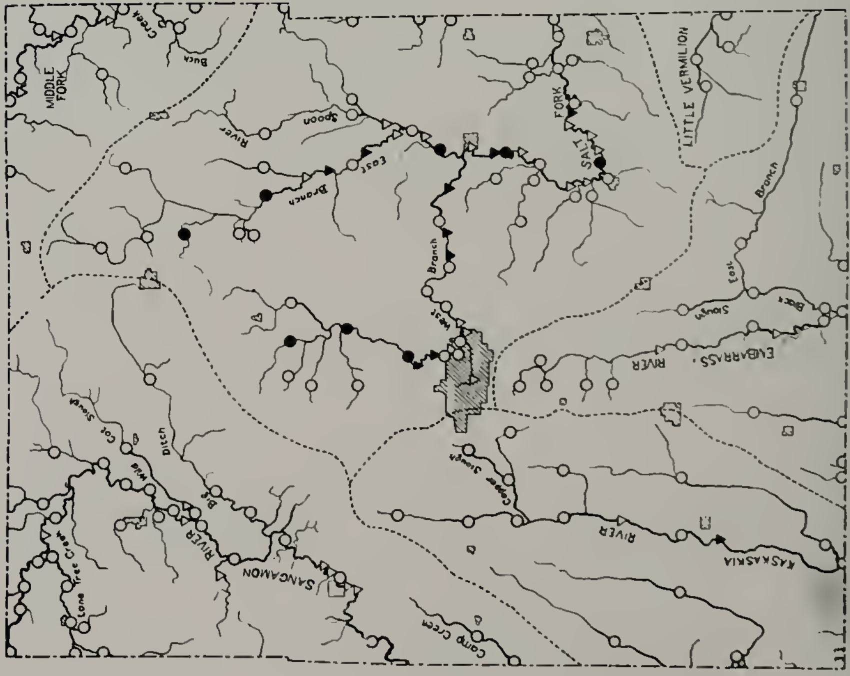
Map 31. Distribution of *Ameiurus melas*—Black bullhead.



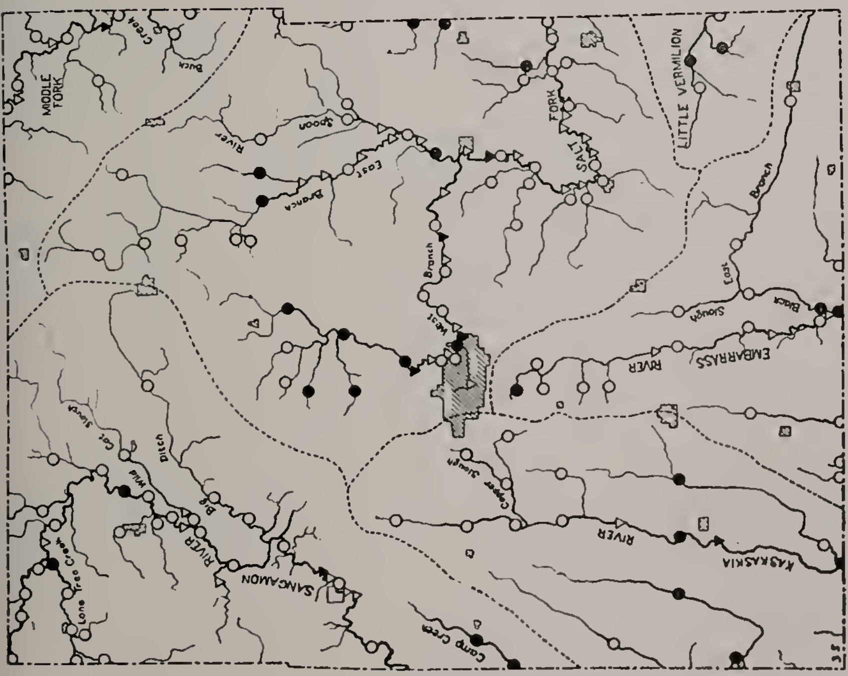
Map 32. Distribution of *Noturus flavus*—Stonecat.



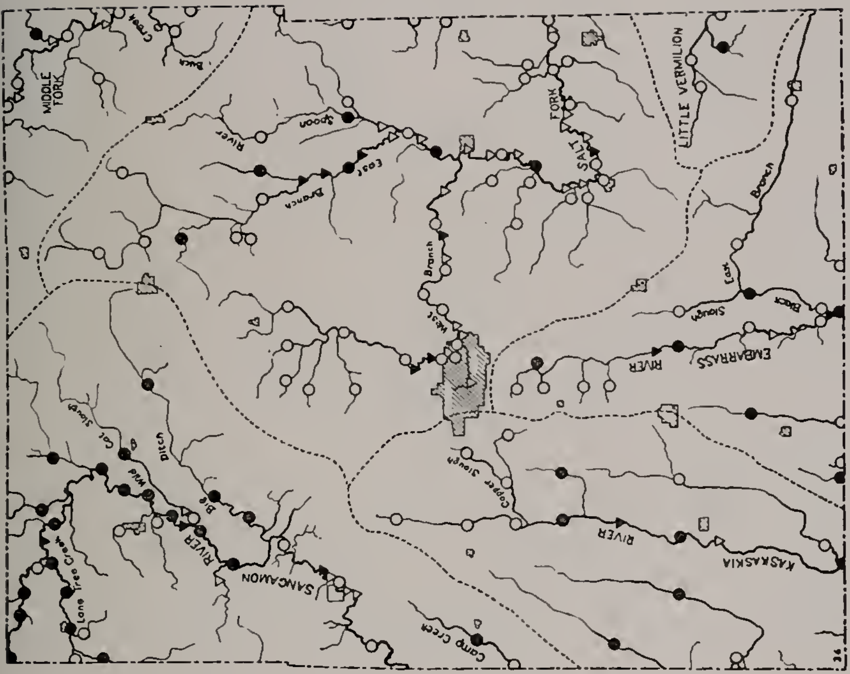
Map 34. Distribution of *Schilbeodes miurus*—Brindled stonecat.



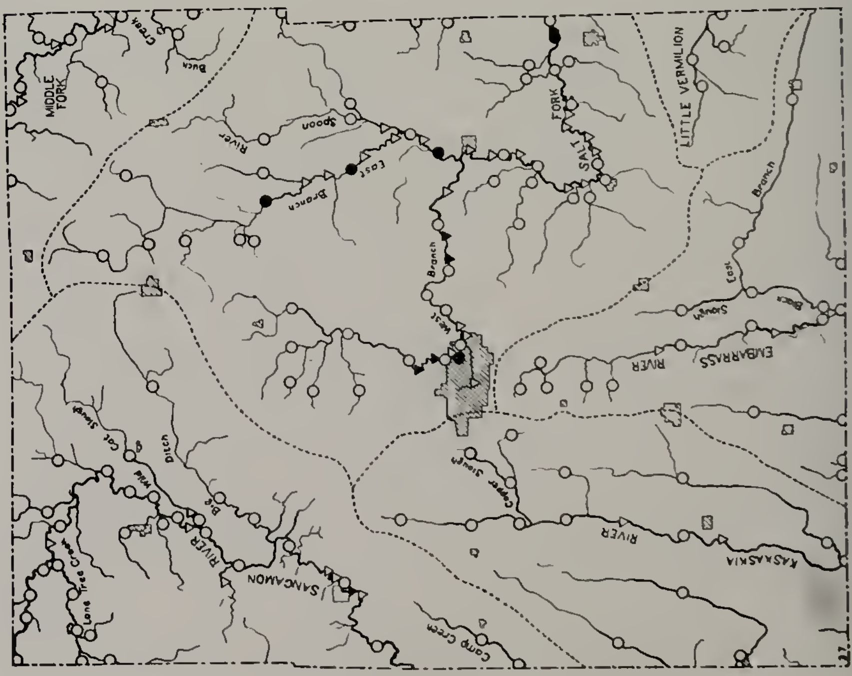
Map 33. Distribution of *Schilbeodes gyrinus*—Tadpole cat.



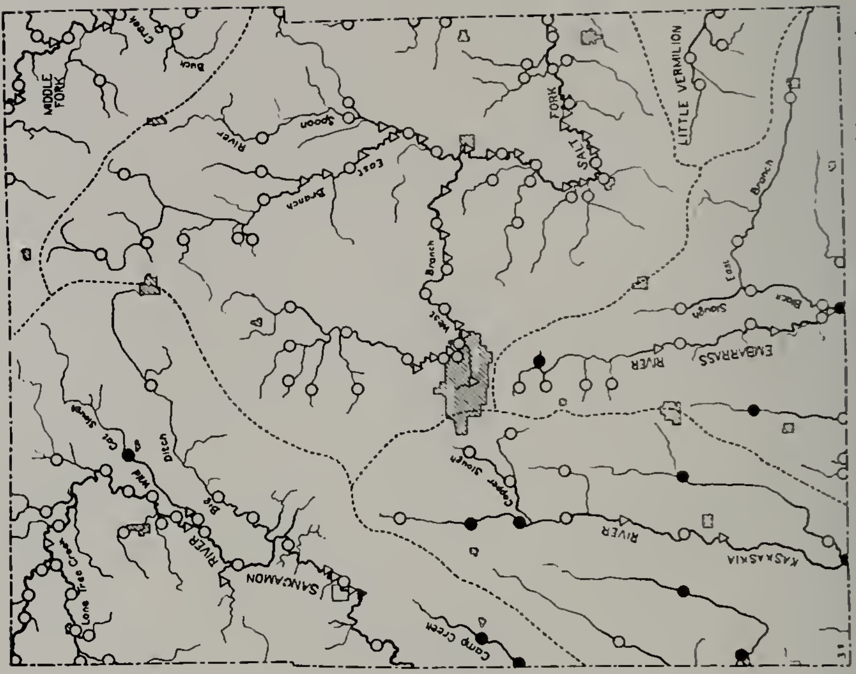
Map 35. Distribution of *Esox vermiculatus*—Grass pike.



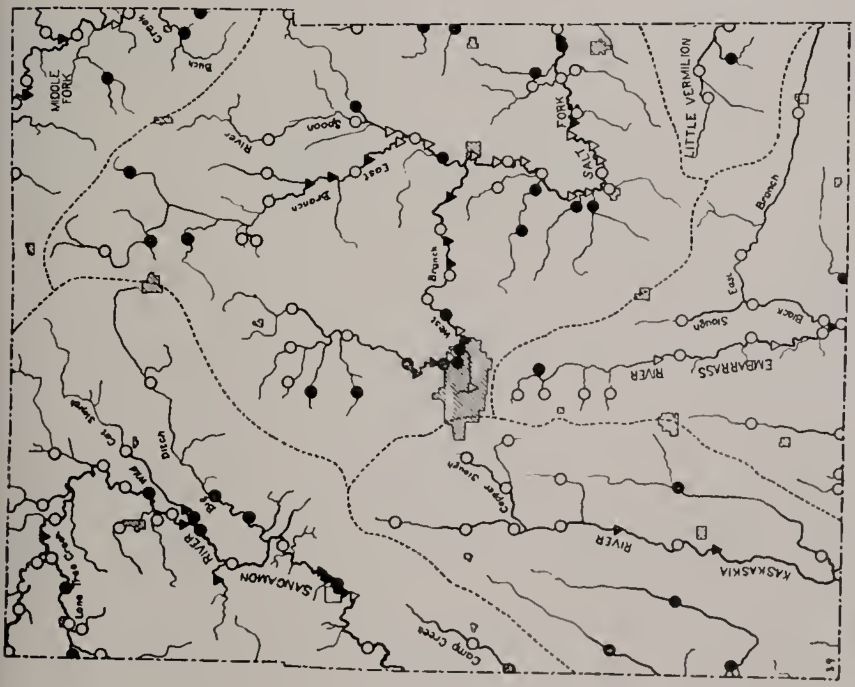
Map 36. Distribution of *Fundulus notatus*—Top-minnow.



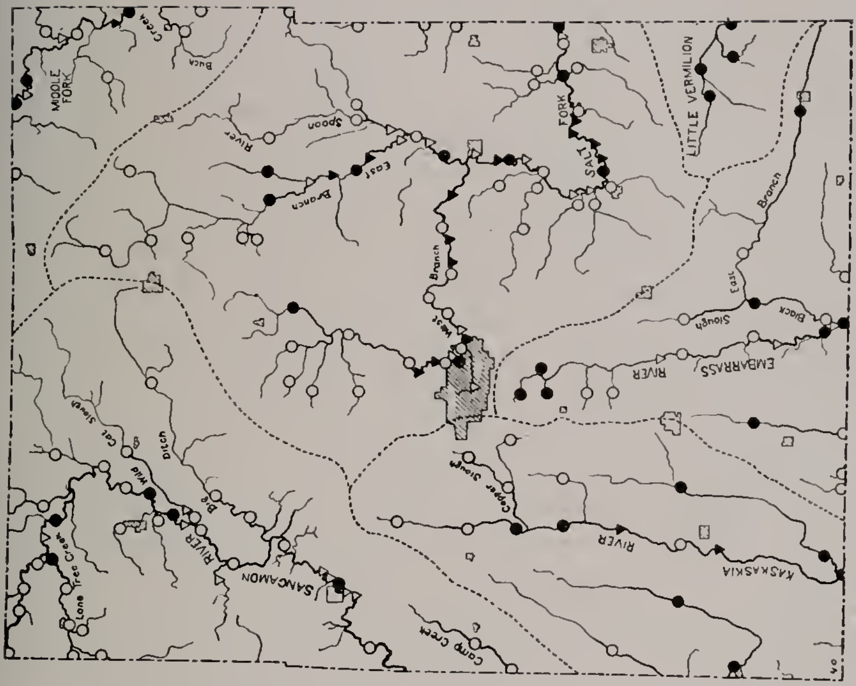
Map 37. Distribution of *Labidesthes sicculus*—Brook silverside.



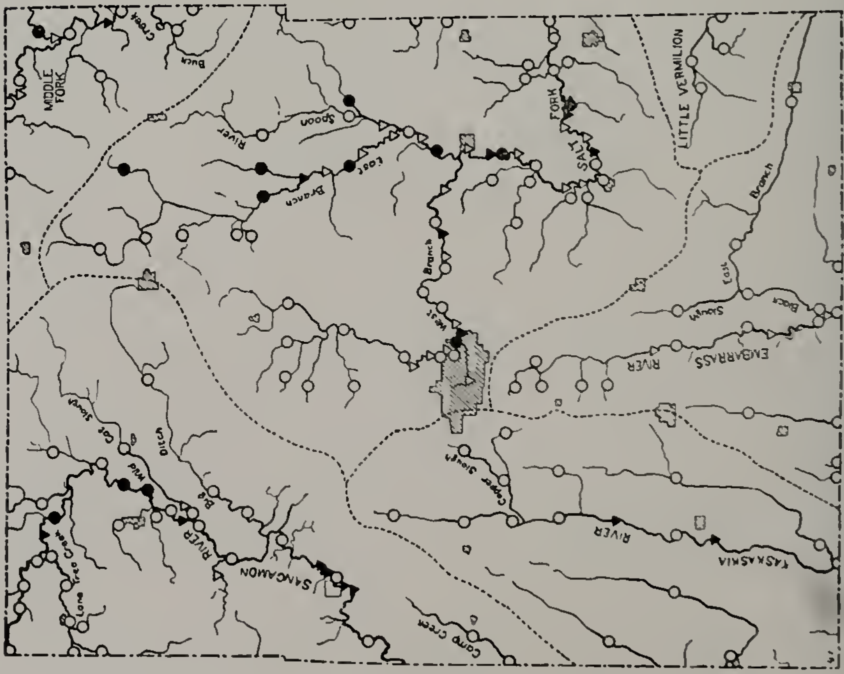
Map 38. Distribution of *Aphredoderus sayanus*—Pirate-perch.



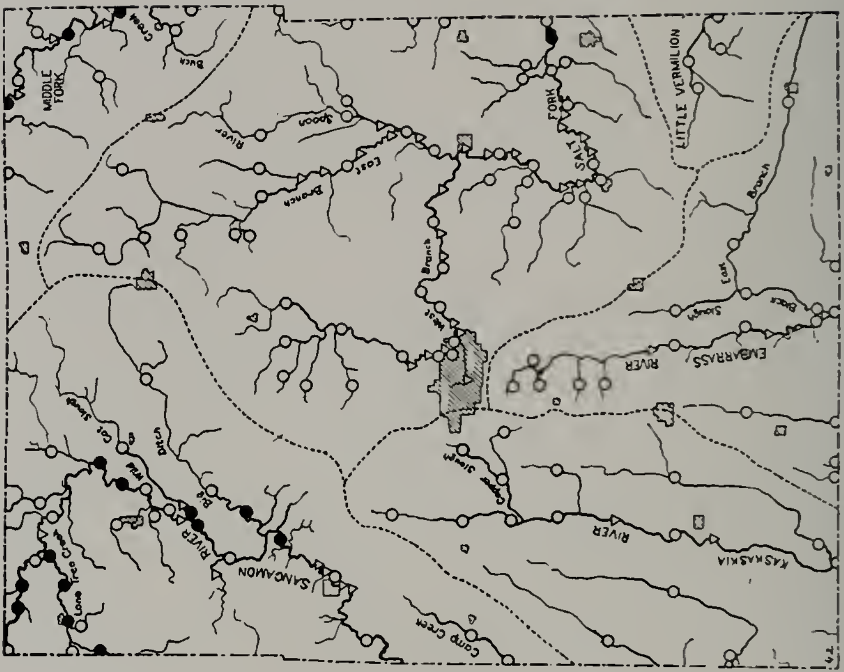
Map 39. Distribution of *Lepomis cyanellus*—Green sunfish.



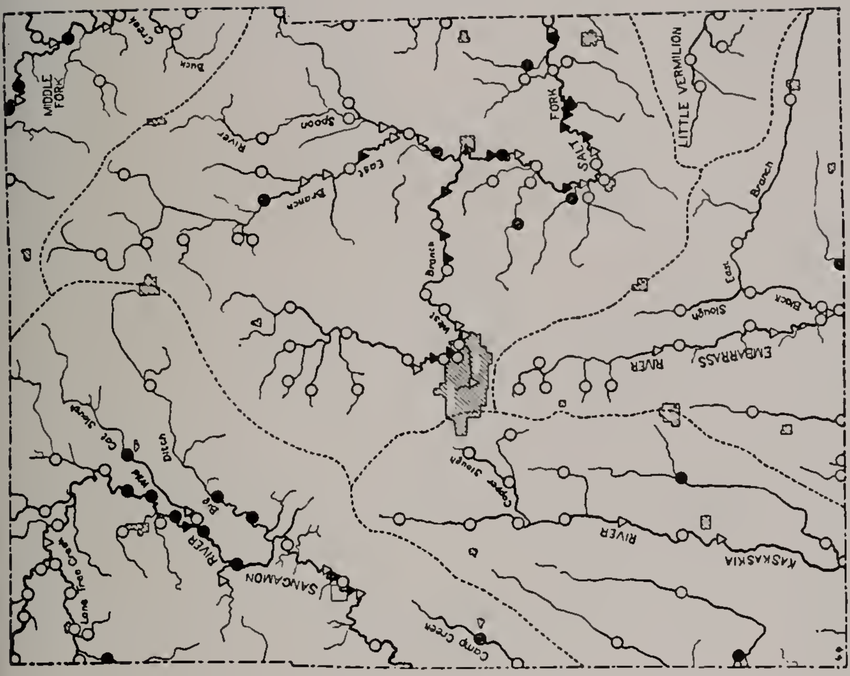
Map 40. Distribution of *Lepomis megalotis*—Long-eared sunfish.



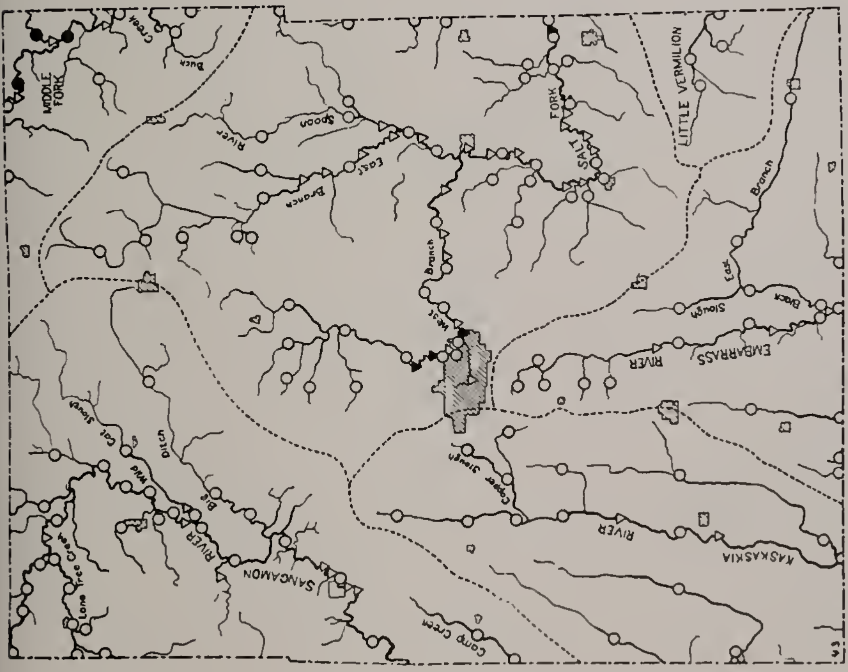
Map 41. Distribution of *Lepomis humilis*—Orange-spotted sunfish.



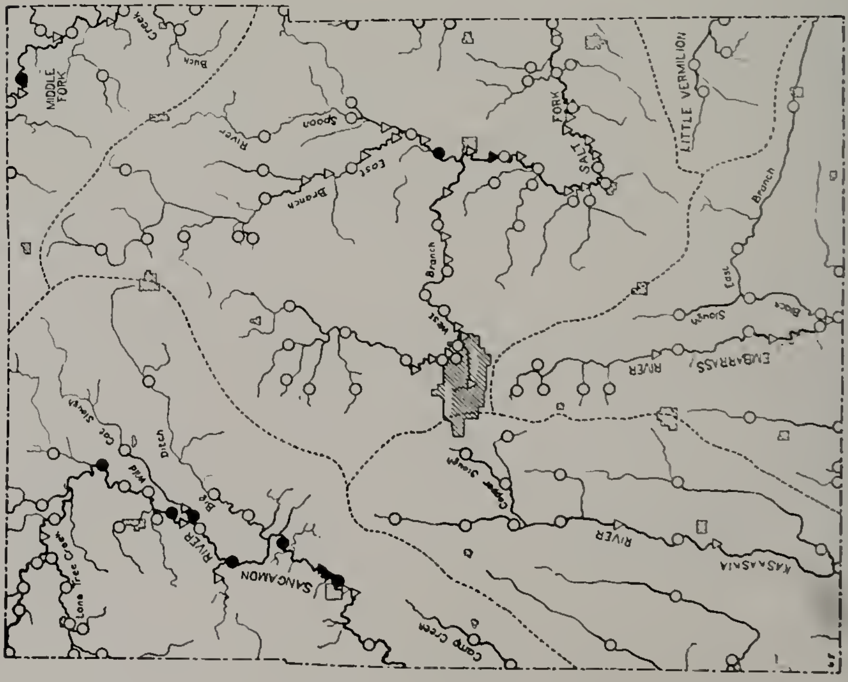
Map 42. Distribution of *Micropterus dolomieu*—Small-mouthed black bass.



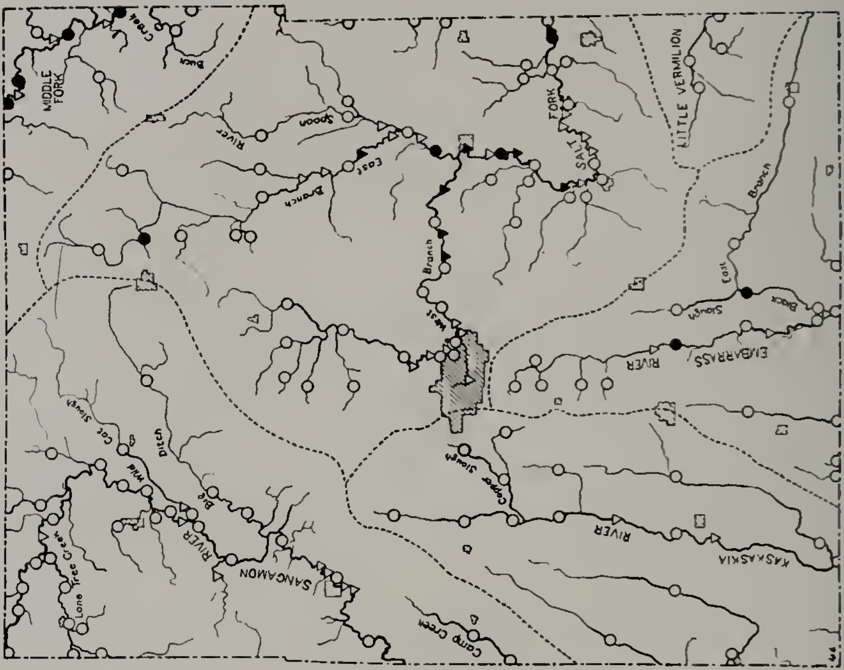
Map 44. Distribution of *Hadropterus aspro*—Black-sided darter.



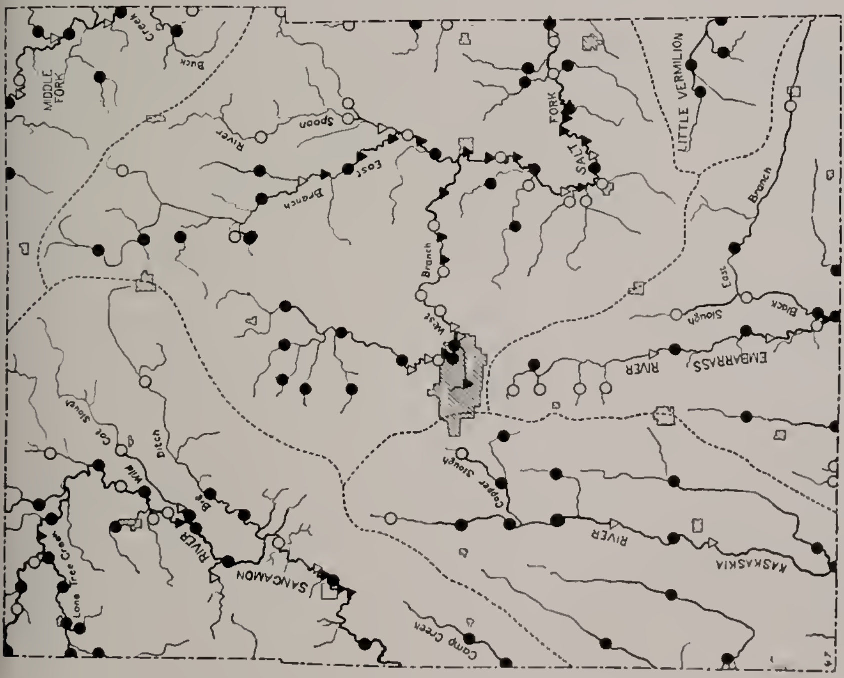
Map 43. Distribution of *Micropterus salmoides*—Large-mouthed black bass.



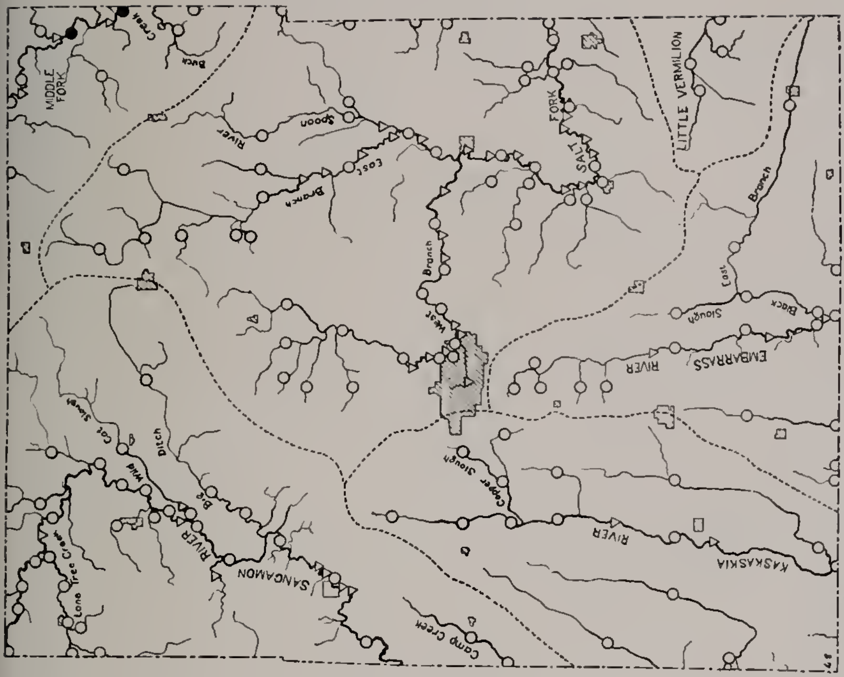
Map 45. Distribution of *Hadropterus phoxocephalus*—Sharp-nosed darter.



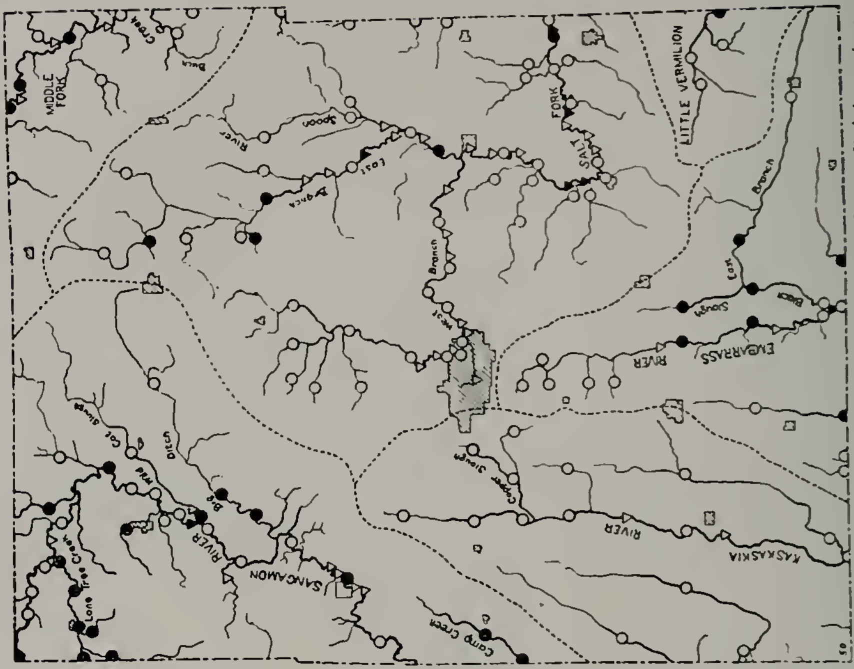
Map 46. Distribution of *Diplesion blennioides*—Green-sided darter.



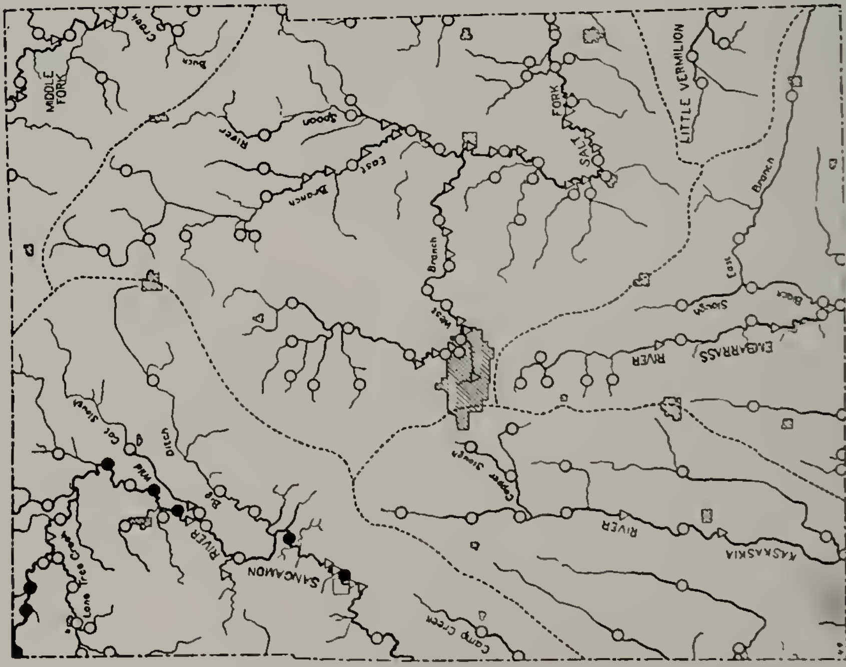
Map 47. Distribution of *Boleosoma nigrum*—Johnny darter.



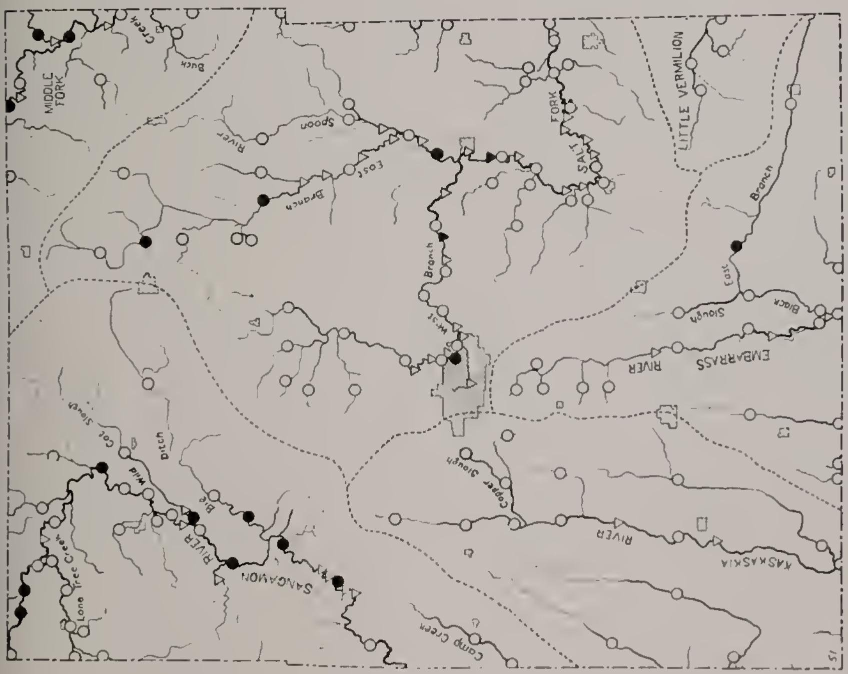
Map 48. Distribution of *Ammocrypta pellucida*—Sand darter.



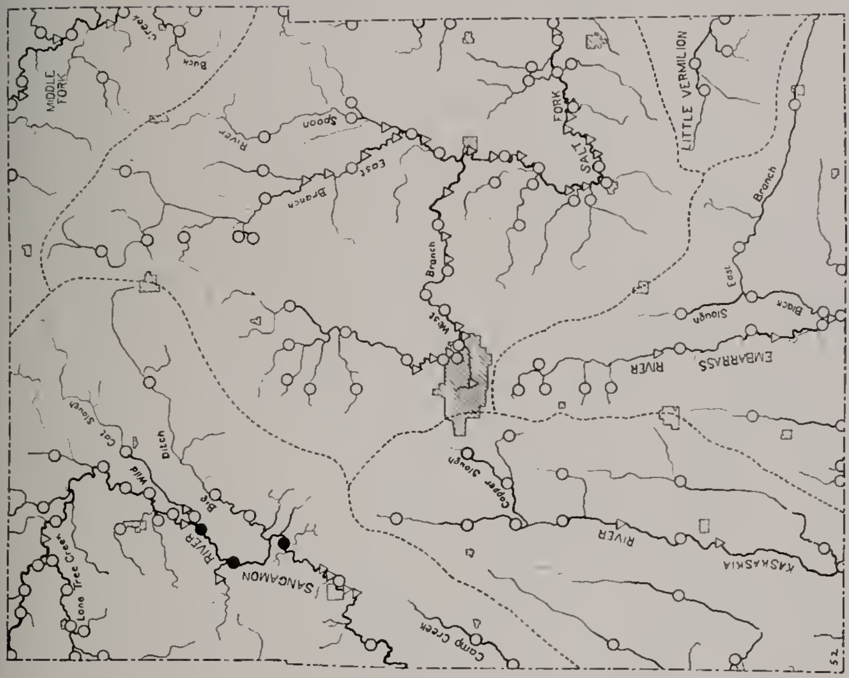
Map 50. Distribution of *Etheostoma coeruleum*—Rainbow darter.



Map 49. Distribution of *Etheostoma zonale*—Banded darter.



Map 51. Distribution of *Etheostoma flabellare*—Fan-tailed darter.



Map 52. Distribution of *Aplodinotus grunniens*—Sheepshead.

APPENDIX

Revised Names of Champaign County Fishes

Names used by Forbes and Richardson in "The Fishes of Illinois." 1909.	Names used by Jordan in "Manual of the Vertebrate Animals of the Northeastern United States." 13th ed., 1929.
Anguilla chrysypa	Anguilla bostoniensis
Ictiobus cyprinella	Megastomatobus cyprinella
Carpiodes velifer	Carpiodes cyprinus
Catostomus nigricans	Hypentelium nigricans
Moxostoma breviceps	Moxostoma macrolepidotum
Pimephales notatus	Hyborhynchus notatus
Abramis crysoleucas	Notemigonus crysoleucas
Chola vigilax	Ceratichthys vigilax
Notropis cayuga	Hybopsis heterolepis
Notropis blennius	Hybopsis deliciosus
Notropis gilberti	Hybopsis dorsalis
Notropis illecebrosus	Hybopsis boops
Notropis whipplii	Cyprinella whipplii
Notropis cornutus	Luxilus cornutus
Notropis pilsbryi	Hydrophlox zonatus
Notropis umbratilis atripes	Lythrurus umbratilis cyanocephalus
Hybopsis amblops	Erinemus hyalinus
Hybopsis storerianus	Erinemus storerianus
Hybopsis kentuckiensis	Nocomis biguttatus
Leptops olivaris	Opladelus olivaris
Schilbeodes exilis	Rabida exilis
Schilbeodes miurus	Rabida miurus
Fundulus notatus	Zygonectes notatus
Lepomis cyanellus	Apomotis cyanellus
Lepomis miniatus	Sclerotis miniatus
Lepomis megalotis	Xenotis megalotis
Lepomis humilis	Allotis humilis
Lepomis pallidus	Helioperca incisor
Micropterus salmoides	Huro salmoides
Hadropterus phoxocephalus	Alvordius phoxocephalus
Hadropterus aspro	Alvordius maculatus
Diplesion blennioides	Etheostoma blennioides
Boleosoma camurum	Vaillantia camura
Ammocrypta pellucida	Vigil pellucidus
Etheostoma zonale	Nanostoma zonale
Etheostoma jessiae	Oligocephalus jessiae
Etheostoma coeruleum	Oligocephalus coeruleus
Etheostoma flabellare	Catonotus flabellaris
Boleichthys fusiformis	Hololepis fusiformis

INDEX TO NAMES OF SPECIES