ILLINOIS NATURAL HISTORY SURVEY
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R. WELDON LARIMORE
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DEPARTMENT OF REGISTRATION AND EDUCATION
NATURAL HISTORY SURVEY DIVISION
Urbana, Illinois

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This paper is a joint contribution from two sections of the Illinois Natural History Survey: the Section of Aquatic Biology, represented by Dr. R. Weldon Larimore, Aquatic Biologist, and the Section of Faunistic Surveys and Insect Identification, represented by Dr. Philip W. Smith, Associate Taxonomist.

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Wildcat Slough, a tributary of the Sangamon River, south of Fisher. The lower part of this stream is typical of the undredged creek in Champaign County; it contains a great variety of fishes.

The Fishes of Champaign County, Illinois,
as Affected by 60 Years of Stream Changes

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The fishes of Champaign County, Illinois, have received probably as intensive and prolonged study as those in any area of equal size in the New World. The long period of observation has furnished an unusual opportunity to evaluate the ecological changes that have occurred in a highly developed agricultural and urban region and to relate these changes to the distribution and abundance of stream fishes.

In 1899 and several years before and after, Stephen A. Forbes and Robert E. Richardson made 48 collections of fishes in Champaign County while gathering material for their study *The Fishes of Illinois* (Forbes & Richardson 1908). Their collections included approximately 65 species. In 1928 and 1929, David H. Thompson and Francis D. Hunt made 132 Champaign County collections that included approximately 75 species (Thompson & Hunt 1930). The exact number of species in these early studies is uncertain because some of the reported species were composites of two or more currently recognized species. Thompson & Hunt's study was aimed at discerning distributional changes in fish. The use of standardized sampling methods and a systematic approach to making collections enabled them to express results quantitatively (to include numbers and weights of fish) as well as qualitatively (to include only names of species) and permitted them to make a number of important generalizations regarding the distribution and abundance of fishes in small streams.

A period of about 30 years elapsed between the study by Forbes & Richardson and that by Thompson & Hunt. As a second 30-year period drew to a close, a unique opportunity to collect data that could be compared with those of Forbes & Richardson and Thompson & Hunt, and to test some of the concepts outlined by Thompson & Hunt, could not be ignored. Accordingly, we undertook a third survey in the summer of 1959 and the spring of 1960. Our investigation was similar to that of Thompson & Hunt, except that, in order to obtain more standardized data, we utilized techniques and refinements unknown in 1928 and 1929. The present paper is the result of the third survey.

Throughout this study, emphasis has been placed on changes—changes in the county resulting from agricultural development and population increase, changes in the streams resulting from natural and human modifications, changes in aquatic habitats resulting from new developments in land use practices, and changes in the fishes as these adaptable animals adjusted to new conditions in their naturally unstable aquatic environment.

ACKNOWLEDGMENTS

We gratefully acknowledge the assistance of three former employees of the Illinois Natural History Survey, David J. McGinty, Richard E. Bass, and David W. Bridges, and regret that we cannot share authorship with them. All of them were active in the investigation during the entire field program and through much of the data analysis. Throughout the summer of 1959, they returned to the laboratory each evening and helped sort, count, and measure collections, frequently of such size that sorting continued until midnight. With equal willingness, they shared, or carried on in our absence, other phases of the study ranging from hard physical labor to tabulation of data. Their contribution is sincerely appreciated.

For kindly answering our questions concerning the 1928 survey and giving his opinion on some of the recent collections, we particularly thank Dr. David H. Thompson. For graciously transcribing his records and field notes on angling in Champaign County, we are grateful to Dr. Marcus S. Goldman.

Dr. Milton B. Trautman and Dr. Reeve M. Bailey checked the identification of some of the difficult specimens. Dr. Horace W. Norton and Mr. Bud J. Meador gave counsel and guidance in analyzing our data. Dr. Thurston E. Larson, Dr. Russell T. Odell, Dr. Robert A. Evers, and Mr. W. J. Roberts offered detailed information relating to their particular specialties.

The photographs were taken by Mr. William E. Clark and Mr. Wilmer D. Zehr; fig. 6 was drafted by Mrs. Alice Ann Prickett; much of the drafting of the distribution on maps was done by Mr. Ralph G. Downer.

We owe a special debt to Dr. George W. Bennett for suggestions and encouragement throughout the investigation and to Dr. Bennett and Dr. H. H. Ross for critical perusal of our early manuscript. We are indebted to Mr. James S. Ayars for his editing of the final manuscript.

The Illinois State Department of Conservation co-operated in this study by supporting part of the field work and laboratory analyses.

METHODS AND EQUIPMENT

Methods and equipment employed in sampling stream fish populations should be selected on the basis of the demands and objectives of the study and the amount of time and effort that can be expended in making the collections. During each of the surveys of the fishes of Champaign County, the procedure was to visit well-distributed sites, selected to yield a comprehensive picture of the fishes of the streams. Seines were used as standard equipment in the first two investigations; during the third survey both seines and electrofishing equipment were employed. The total time spent procuring collections may have doubled with each succeeding survey. These changes in procedure and intensity of collecting present difficulties in comparing results of the three surveys. In drawing conclusions, we have carefully weighed the difficulties inherent in a study extending over more than half a century.

Forbes & Richardson Procedure

Forbes & Richardson (1908) made their collections by seining, presumably with seines of various mesh sizes, at selected sites throughout the county. As far as we know, these early investigators made no attempt to do a uniform amount of seining at each station or to determine the relative abundance of the various species found. The number of revisits, if any, that they made to their stations cannot be ascertained. According to Thompson & Hunt (1930:16), the collections of Forbes & Richardson spanned a 20-year period: 1 in 1882, 3 in 1885, 1 in 1892, 2 in 1898, 22 in 1899, 3 in 1900, and 8 in 1901, giving a total of 40 collections from 40 stations. Apparently these counts were made from the old accession catalogs and the atlas of maps that accompanied Forbes & Richardson's *The Fishes of Illinois.* They do not agree with our calculations. Our count of localities plotted by Forbes (1907) and by Forbes & Richardson (1908) and of localities represented by specimens still extant at the Natural History Survey from early collections raises the number of Champaign County localities sampled by Forbes & Richardson to 48, distributed by drainages as follows: Salt Fork 27, Sangamon 10, Kaskaskia 5, Embarrass 3, and Middle Fork 3.

Thompson & Hunt Procedure

Thompson & Hunt (1930:14–7) employed seines of certain lengths and mesh sizes. They recorded the actual number of fish taken at each collecting station and the calculated number per 100 square yards of area seined. In the words of Thompson & Hunt (1930:5), "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." Records show that 126 stations were sampled in 1928 and that a few stations were revisited in the spring of 1929. Of the total number of collections, 132, Thompson & Hunt (1930:14–7) made 127 with a seine, 10 feet by 4 feet, having meshes one-sixth inch square and 5 with a seine, 75 feet by 6 feet, having meshes 1 inch square. Their 126 stations were distributed by drainages as follows: Salt Fork 48, Sangamon 31, Embarrass 19, Kaskaskia 15, Middle Fork 9, and Little Vermilion 4. Thompson & Hunt emphasized, and demonstrated with amazing success, the importance of skill and efficiency in sampling with seines. The distribution of the Forbes & Richardson and the Thompson & Hunt collecting stations is depicted in fig. 1.

1959 Survey Procedure

The intention, when our survey was being planned, was to duplicate the seining procedures employed by Thompson & Hunt and in addition to extend the sampling at each station by using more efficient, recently developed methods that would lead to quantitative samples of greater reliability. We soon realized, however, that it would be virtually impossible to duplicate their seining proce-

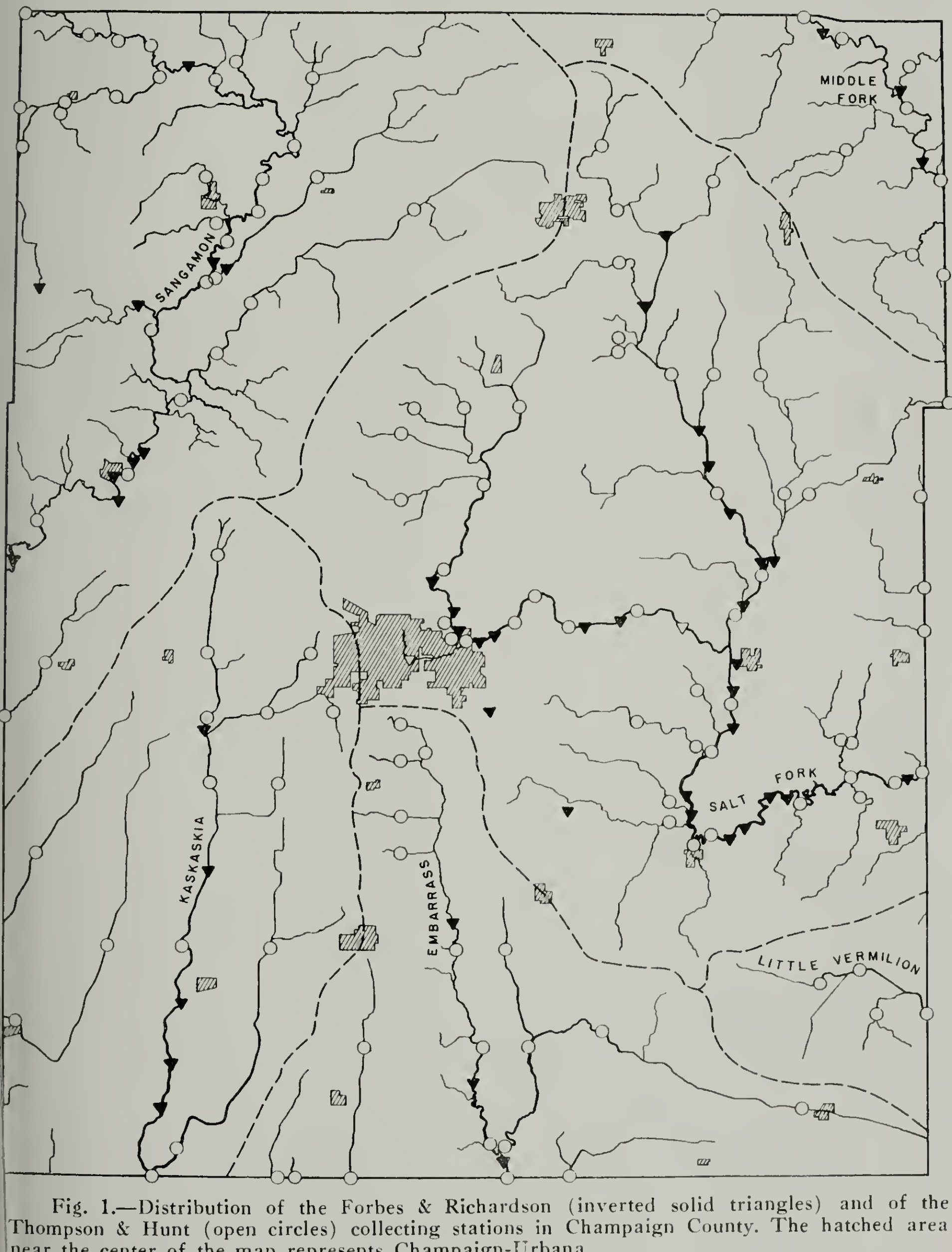

Fig. 1.—Distribution of the Forbes & Richardson (inverted solid triangles) and of the Thompson & Hunt (open circles) collecting stations in Champaign County. The hatched area near the center of the map represents Champaign-Urbana.

Fig. 2.—Seining a shallow, rocky riffle in the Sangamon River near Mahomet. Agitation upstream from the seine dislodges darters, madtoms, and certain minnows from the gravel.

dures, and that even a slight change in technique could strongly influence any quantitative value of the sample. We therefore chose a standard procedure of blocking off a section of stream and collecting the fishes within the section with an electric fish shocker. In efforts to extend our list of species in the area, we then seined various habitats close to the blocked-off section.

Selection of Site.—Because of the uneven distribution of fishes in a stream, the selection of a sampling station was of considerable importance. Inasmuch as Thompson & Hunt had mapped the location of each of their sites before going into the field, and their maps, on file at the Natural History Survey, were available to us, we chose to revisit their stations. However, we did not necessarily sample at exactly the same places. Their notes indicated that they often seined unusual situations such as deep pools generally found under bridges, whereas we attempted to select areas judged representative of particular parts of streams. Although our procedure possibly omitted some unusual populations, it produced samples that we believe were more nearly representative of each drainage system.

Sampling Technique.—At each selected site, a stretch of stream approximately 150 feet long was blocked off with one-fourth-inch-mesh minnow seines. A crew of three or four men started at the downstream block with an electric seine and proceeded upstream, collecting all fish that could be seen and captured with dip nets of three-sixteenths-inch mesh. On reaching the upstream block, the crew reversed direction, electrofishing back through the sample area. When the water was exceptionally turbid, a minnow seine was pulled through the enclosed area to recover stunned fish that had been overlooked by crew members using dip nets. Care was exercised to pick up all of the dead and stunned fish that had drifted into the net at the downstream block.

The electric seine used in the small streams was 30 feet long; it had 15-inch drop electrodes spaced at 30-inch intervals. It was powered by a gasoline-driven electric generator having a maximum capacity of 8.7 amperes of 60-cycle alternating current at 115 volts. In wider streams, a 50-foot electric seine, powered by an 11-ampere, 230-volt alternating current generator, was used. The generator was usually left near the equipment truck, and the electric lead wires were run off a reel having a commutator through which power was supplied as the electrodes were moved up and down the stream.

In the blocked-off areas, we took 77 samples, all within a short period of time (July and August, 1959), thus keeping at a minimum the effects that seasonal changes in fish distribution and abundance might have on our samples. Because for each blocked-off area we made and kept a record of the number of individuals of each species in the sample and their total weight, we refer to a sample from such an area as a quantitative sample.

To supplement the sample taken within each blocked-off area, we seined nearby habitats, figs. 2 and 3. An indefinite number of hauls was made with a 20-foot by 4-foot nylon minnow seine of three-sixteenths-inch mesh. These "cruising" samples usually added several species to the list of fishes taken at each locality. Material obtained outside the blocked-off areas was not included in the quantitative samples. Fish in the "cruising" samples were not measured or weighed.

The reliability of our quantitative samples was not determined. We recognized the selectivity of electrofishing in different habitats and for different species of fishes. For obvious practical reasons, we could not adapt our equipment and procedure to produce the greatest efficiency

Fig. 3.—Seining a shallow pool in the Sangamon River near Mahomet. Habitats of this type contain suckers and minnows. In 1959, collecting with a minnow seine in such habitats usually yielded species not collected with an electric seine in nearby blocked-off areas.

at each station, nor could we determine the efficiency of our electrofishing at each station and still complete the field work in a 2-month period. To keep the number of variable conditions as small as possible and to obtain as nearly comparable samples as was practical, we followed the same procedure at each station. In another study Larimore (1961), using equipment and procedures similar to those used in the 1959 survey, determined electrofishing success in a stream just outside Champaign County. Since the stream was similar to some of the Champaign County streams and since many of the same species were collected, his rate of success is pertinent to evaluating our quantitative samples.

The qualitative completeness of our quantitative samples, that is, the number of species per station in the quantitative samples compared with the number of species per station in the quantitative plus other samples (total collection per station), is shown in tables 13 and 14. Usually about 90 per cent of the species listed at each station were taken in the blocked-off area; the additional 10 per cent were obtained in nearby areas. Our collections averaged 1.4 times as many species per station as did those of Thompson & Hunt. The difference is due probably to our use of two collecting methods and our larger samples. It probably does not reflect a change in the number of species present, nor does it imply inefficiency in the earlier survey, for certainly Thompson & Hunt were remarkably thorough with the method that they employed.

Further evaluations of our collecting efficiency are given in the section General Abundance and Occurrence.

Preservation and Sorting of Collections.—Very large, easily identified fishes were released at the site of capture after their numbers, lengths, and weights had been recorded. All small specimens were immediately put into cans of 15 per cent formalin and taken to the laboratory. Each evening, individuals in the collection were sorted; then, for each species, the numbers, total weights of various size groups, and ranges in lengths were recorded on printed form cards. Only specimens of unusual interest were saved for the permanent collection. Specimens obtained from habitats adjacent to the blocked-off areas were not included in quantitative computations.

Habitat Data Recorded at Site.—A series of standard measurements and an evaluation of certain ecological factors were made at each station. Water level was recorded as high, low, or normal. At each station, depth was measured along transects at the middle and lower part of the study area and in the deepest part of the area. Where great variation in depth occurred, additional measurements were taken halfway between the middle and upper limits and the middle and lower limits of the area. Maximum, minimum, and average widths were recorded on a sketch of the stream section. Current was measured by timing a float as it passed through a 50-foot course judged representative of the water velocity at the station. Turbidity was measured with a U. S. Geological Survey turbidity needle. Types of bottom materials, such as sand, silt, and gravel, were determined, and an estimate was made of the relative abundance of each type. Notes were made of debris and vegetation in the stream, as well as of vegetation on the bank and overhanging the water.

Tabulations.—Quantitative data were recorded on large tabular sheets similar to those used by Thompson & Hunt. Total number and weight for each species in a collecting area were translated into number and weight per 100 square yards of area. This procedure facilitated comparison of our results with those of Thompson & Hunt. The volume of water at each station was calculated and recorded, so that the relations of fish numbers and weights to volume could be ascertained. Also, the measurements and ecological evaluations discussed above were recorded on each sheet. All of this information was transferred to International Business Machine (IBM) punch cards; the results of the classification and analysis of these data were recorded on IBM work sheets, which along with the original tabulations and pertinent notes for both our survey and that of Thompson & Hunt are on file at the Natural History Survey offices.

Supplemental Distribution Records.—In addition to making collections at most of the stations set up by Thompson

& Hunt, we sampled 28 other localities in the county. In sampling these stations, we used either a 20-foot by 4-foot nylon minnow seine of three-sixteenths-inch mesh or a rowboat shocker (Larimore, Durham, & Bennett 1950). The seine sampling, aimed at filling in distributional gaps where blocked-off sampling stations were widely separated, was of varying intensity and was designed merely to procure a list of species from each locality. Rowboat shocking had the same objective and, with few exceptions, was used only when the stream was too large to permit the effective use of minnow seines. Some sampling by both methods was done on re-

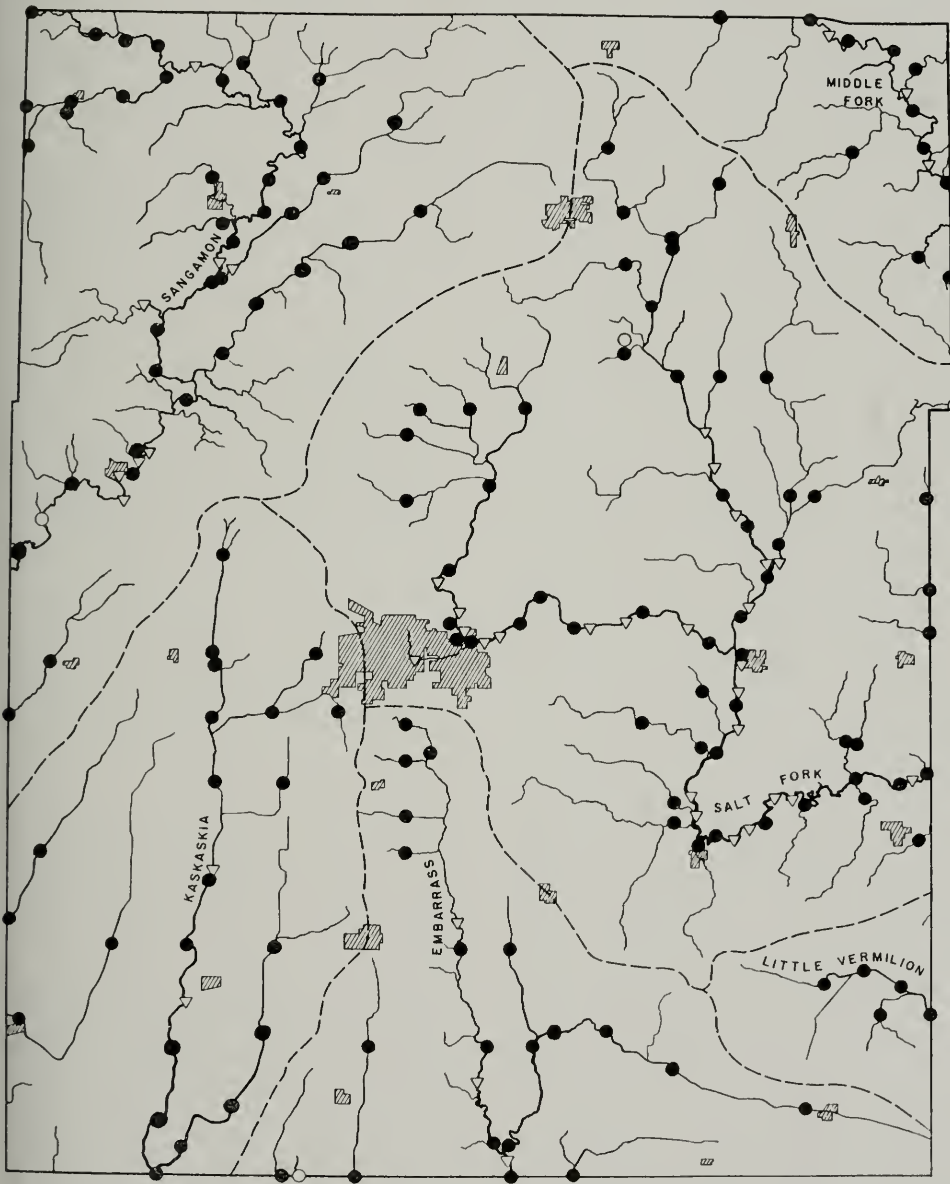

Fig. 4.—Distribution of the 1959 collecting stations (solid circles) in Champaign County. Open symbols represent collecting sites, not revisited in 1959, of the two prior surveys: inverted triangles the Forbes & Richardson survey and circles the Thompson & Hunt survey.

visits to certain stations in an attempt to obtain unusual species that had not been taken on our initial visits, but that had been recorded at the stations by Thompson & Hunt. The streams sampled and the number of collecting stations on each stream, including stations for cruising and supplemental sampling, were as follows: Salt Fork 55, Sangamon 39, Kaskaskia 22, Embarrass 20, Middle Fork 11, and Little Vermilion 5. The distribution of these 152 localities is depicted in fig. 4.

Sources of Additional Information.—Several Champaign County anglers provided reliable observations. The records they provided were evaluated separately from those of our own collections; their degree of reliability is fully indicated in the Annotated List of Fishes. Two operators of commercial fee-fishing lakes provided information that was used.

DESCRIPTION OF COUNTY

In about a century, much of Champaign County has been converted from marshland infested with deer flies to well-drained, fertile farmland. It has been intensively cultivated for several decades, and its streams have been modified by dredging, tiling, silting, and other influences that accompany agricultural practices. The human population has mushroomed in recent years, and some areas have become industrialized, providing an opportunity to observe the effects of sewage and industrial wastes on streams and stream life.

Located in east-central Illinois, Champaign County, fig. 5, is 36 miles from north to south and 27 miles from east to west. It occupies 988 square miles (632,415 acres) of flat to slightly rolling land; the present relief resulted from relatively recent glaciation and from postglacial stream erosion. The altitude ranges from 630 to 860 feet above sea level and averages about 710 feet. Although essentially a flat plain, it is somewhat higher than surrounding counties, and four major stream systems arise within the county. Two other stream systems originate a short distance north of the county limits.

The county has been glaciated twice, but the effects of the more recent Wisconsin stage (about 18,000 years ago) obscure those of the much older Illinoian stage. The series of end moraines, which rise from 50 to 100 feet above the intermorainal basins, usually form boundaries between drainage systems. The entire

Fig. 5.—Location of Champaign County and its streams in relation to the state and major drainage systems. The dotted line indicates the boundary of a particularly fertile area, at one time mostly prairie marsh.

county is overlaid with a mantle of Wisconsin glacial till, which is covered with a layer of loess of varying thicknesses up to 8 feet, except where the loess has been eroded away. The county contains no rock outcrops.

Soils

The soils reflect the soil parent material, the drainage, and the vegetational history of the area. Dark upland prairie soils make up about 92 per cent of the area; yellow-gray silt loams, the upland timber soils, make up about 5 per cent; bottomland or terrace soils constitute the small remainder (Hopkins *et al.* 1918:6).

A recent arrangement of the soil types of Champaign County is presented in the following paragraph (Fehrenbacher 1963 and personal communication from Dr. Russell T. Odell, Professor of Soil Pedology, University of Illinois).

The dark upland prairie soils can be placed in four general groups. A group of silty loess prairie soils (mainly Drummer, Flanagan, and Catlin soil types) covers about 40 per cent of Champaign County. These soils are loam till covered with 3 to 5 feet of loess. Properly managed, they are the most productive in the county, averaging about 95 bushels of corn per acre per year. A second group of prairie soils, mainly Drummer, Brenton, and Proctor soil types, consists of silty outwash soils with greater subsurface flow and higher permeability than the first group mentioned. They cover about 26 per cent of the county and also are very productive. This group of soils is associated with the former marshes. A third group, made up of medium-textured prairie soils, occurs in rolling areas mostly along the Champaign Moraine and covers about 10 per cent of the county. A fourth group, composed of fine-textured prairie soils of silty clay loam and silty till, covers a large area in the northeastern part of the county and scattered areas in the northwestern part, a total of 16 per cent of the county. This group is somewhat less productive than the other prairie soils. The small remaining group, consisting of nonprairie soils, is generally associated with the river valleys and constitutes the least productive soils in the county.

Weather

Champaign County has a temperate continental-type climate without the modifying influences of a large body of water. In most years, temperature extremes range from well below 0 degrees to slightly over 100 degrees F. The annual mean temperature is 52 degrees F. (Changnon 1959:46). Comparison of monthly average temperatures over a 57-year period during which weather records have been kept at Urbana reveals great fluctuation but no significant trend. August, the month of our most intensive collecting in 1959, was considerably warmer than the August average.

The county receives an average of about 36 inches of precipitation per year. Although the annual averages for 1929–1958 were similar to those for the preceding 1903–1928 period, judged by data graphically presented by Changnon (1959:11), the 5-year period immediately preceding Thompson & Hunt's study was exceptionally wet, and the years 1930, 1953, 1954, and 1956 were exceptionally dry, the annual rainfall being less than 30 inches. The years 1940 and 1959 received subnormal amounts of precipitation and were marked by unusually dry summers. The summer months of 1959 were extremely dry and resulted in low water levels during the time of our intensive field work.

Agricultural Practices

Champaign County is one of the most productive grain areas in the world. During more than a century of farming, this county has undergone great changes in landscape, in farming methods, and in crops. These changes include the draining of the wet prairies and marshes to convert them to productive farmland, the use of large machinery, and the widespread use of commercial fertilizers and new and improved plant varieties.

The farming of the first settlers in this county was largely restricted to raising cattle and small crops on the high areas and along the stream courses where drainage was naturally good. Lands that were dry enough for cultivation were turned by oxen. During the last quarter of the nineteenth century, ditches were dug and tiles laid to drain the wet prairie fields. By 1900, the farms averaged between 80 and 100 acres in size.

With the development of large farm machinery—heavy tractors, combines, seeders, and corn pickers — many farms were merged to form larger ones. Currently, the average Champaign County farm is about 200 acres. Within the past 30 years a trend toward less diversification among farm crops has appeared; corn and soybeans have become the two leading crops.

During the 1940's, the widespread use of commercial fertilizers brought about a general increase in average yield. Hybrid plants and improved varieties added to yields. Recently, liquid nitrogen as a fertilizer has further increased production.

At the time of settlement of Champaign County, very little soil eroded from the prairie and timber areas, but intensive farming made erosion a serious, constant threat even in the nearly flat or gently sloping lands of Champaign County. As the native vegetation was removed and the soil directly exposed to rain and wind, the soil became compact and less absorbent, causing more rapid runoff, accompanied by the loss of rich topsoil. The inadequacy of soil conservation practices had adverse effects upon the streams and contributed to more frequent floods followed by seriously low water levels. The effects of soil erosion and the need for intensive conservation methods are not fully appreciated by many Champaign County farmers. Few grainfields are farmed on the contour, strip cropping is rare, and grass waterways are maintained in relatively few of the cultivated fields. Farm animals are permitted to graze the stream banks and thereby contribute to serious erosion and siltation.

Population, Urban, and Industrial Developments

During the first half of the twentieth century, striking changes in land use in Champaign County were brought on by the increasing human population. In 1900, the census reported 47,622 people residing in the county; in 1930, 64,273; in 1960, 132,436. The trend has been toward urbanization; in 1900, 31.1 per cent of the population lived in urban areas and, in 1960, 75.6 per cent. Although there are about 26 cities and villages in the county, only Champaign-Urbana, Rantoul, and a few others have increased in population. Some of the small villages in the county have remained static in population or have even declined. The changes in size of urban areas is illustrated by fig. 6, which shows the village limits of the 1870's in red and the recent limits in black.

A considerable acreage of farmland has been usurped by urban and surburban development. The total number of acres in cultivation was roughly the same between 1900 and 1928 and was considerably greater than it is today. Since 1928, cleared land, particularly that marginal to cities and villages, has been pressed into nonagricultural uses. Many areas that were once farmed now are covered by modern schools, grain storage units, and industrial developments; other large land areas now are occupied by Chanute Air Force Base and the campus of the University of Illinois. These lands are permanently out of production of farm crops. The vast network of roads, including several major highways that transect the county, occupies a large and ever-increasing area.

A highly developed road system has made Champaign County ideally suited for the study reported here because roads are laid out, orderly and regularly, parallel to each other at mile or half-mile intervals throughout the county. All streams could be sampled conveniently at almost any point, and electrofishing and other heavy collecting gear could be transported by automobile almost to the water's edge.

Stream Drainages and Courses

The stream drainages of Champaign County can be summarized as follows. Six rivers have headwater channels in the county, four of which (Salt Fork, Embarrass, Kaskaskia, and Little Vermilion) actually originate within the county. All of the drainages are separated by moraines, except the Sangamon and Salt Fork; during times of flood, headwaters of the Sangamon and Salt Fork may connect, although connection occurs much less frequently now than formerly. The total drainage area (in square miles) of each of these rivers within the county is as follows: Sangamon 277, Salt Fork 346, Middle Fork 69, Embarrass 138, Kaskaskia 168, and Little Vermilion 40. A few smaller streams flow out of the county, but each joins one of the six larger rivers a short distance beyond the county border. The relationships of the streams to the larger rivers are shown in fig. 5.

The total drainage area (in square miles) of the main course of each of these rivers at the point the river leaves Champaign County is as follows: Sangamon 388, Salt Fork 307, Middle Fork 241, Embarrass 106, Kaskaskia 98, and Little Vermilion 28. These figures include upper reaches of those rivers that rise outside the county.

Water Discharge.—Annual average discharge records for two gaging stations near the periphery and for three stations well within the county are available, table 1. The records show the size of the streams at these stations and indicate the amount of water drained from the different watersheds. Calculated from figures in table 1, the annual average discharge of water per acre in the period ending in 1957 was 0.7 cubic feet per second (c.f.s.) for the Sangamon, Salt Fork, and West Branch; 0.6 c.f.s. for the Kaskaskia; and 1.0 c.f.s. for the Bone-

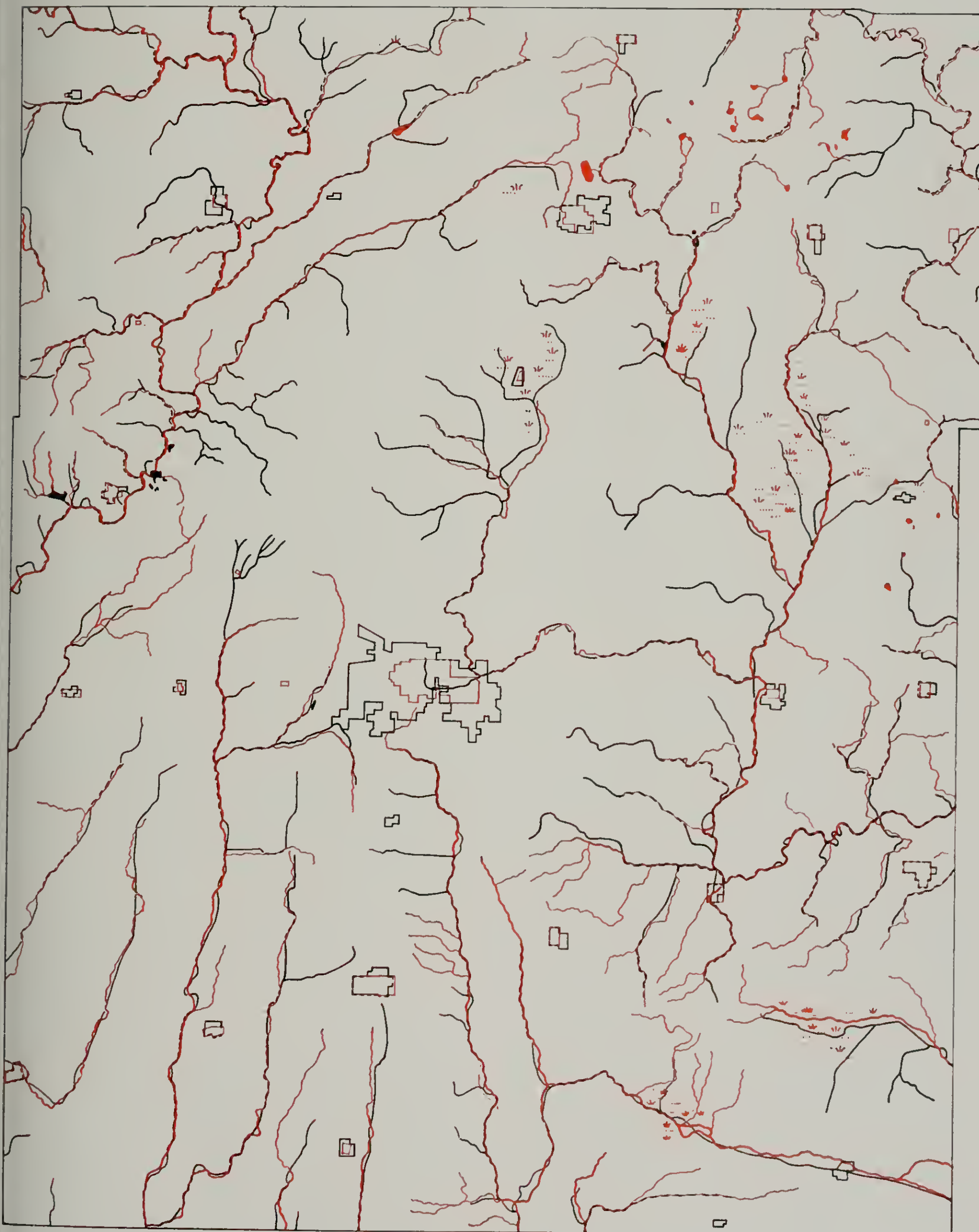

Fig. 6.—Distribution of towns and water areas in Champaign County in the 1870's (in red) and 1950's (in black). Drawn from map in Atlas of the State of Illinois (Anon. 1876) and U. S. Geological Survey Quadrangles (editions 1950–1957).

Table 1.—Water discharge records taken at five gaging stations in Champaign County (U. S. Geological Survey, 1953–1960).

Stream	Location of Station	Watershed, Square Miles	Annual Average Discharge (c.f.s.)	Years of Records
Sangamon	Near Mahomet	356.0	249.00	1948–1957
Salt Fork	Near Homer	344.0	243.00	1944–1957
Kaskaskia	Near Bondville	12.3	8.05	1949–1957
Boneyard	Near Urbana	4.6	4.62	1948–1957
West Branch	Near Urbana	71.4	50.40	1936–1957

yard. The lowest discharge per acre was for the Kaskaskia drainage, which is entirely farmland, and the highest discharge was for the Boneyard drainage, which is almost entirely urban, lying within Champaign-Urbana.

The records on the Sangamon River taken near Monticello are of special value in that they show changes in stream discharge over a long period. Although the gaging station is about 10 miles outside Champaign County, it records the runoff from one-quarter of the county. Records are nearly complete back to 1908. They show that annual average discharge fell below 200 c.f.s. only once during the two decades before the Thompson & Hunt study of 1928, but fell below this level eight times in the three decades since. The low discharges in recent years indicate the reduced water-holding capacity of soils of the watershed. The river now responds quickly to precipitation or drought, whereas it had a more nearly constant flow before 1928.

The minimum discharge of a stream has great significance to fish distribution. Before the Thompson & Hunt study, there was no record of the Sangamon River discharge dropping as low as 1.0 c.f.s. but it reached 1.0 c.f.s. or lower five times in the three following decades. As might be expected, there is a high correlation between precipitation and water discharge of streams in an area. There is, of course, a variable time lag between precipitation and discharge.

Draining and Dredging.—Because of the original marshy character of Champaign County, much draining, dredging, and straightening of waterways has been necessary to prepare the land for agriculture.

The Illinois Farm Drainage Act of 1879 encouraged the formation of drainage districts and enabled farmers to participate in the installation of drainage systems to serve large areas. Drainage proceeded rapidly during the following two decades, and, by the turn of the century, when Forbes & Richardson made the first extensive fish collections in the area, 36 per cent of the county's 632,415 acres had drainage improvements, table 2.

The number of acres in drainage districts almost doubled between 1900 and 1910, with 190,205 additional acres (30 per cent of the county) receiving drainage improvements. In the decades since 1910, the amount of new land drained has declined, table 2. The acreage of land placed in drainage districts in the three decades between 1930 and 1960 amounted

Table 2.—Acres of land in Champaign County placed in drainage districts during each period since about 1880 and the per cent of the county (632,415 total acres) with drainage improvements by the end of each decade. Information from the Federal Land Bank of St. Louis and Champaign County records.

Period	Acres Placed in Drainage Districts	Per Cent of County with Drainage Improvements
Pre–1891	162,298	26
1891–1900	66,951	36
1901–1910	190,205	66
1911–1920	23,524	70
1921–1930*	24,174*	74*
1931–1940	22,838	77
1941–1950	16,064	80
1951–1960	14,046	82

*In 1921–1930, 3,060 previously unrecorded acres that had received drainage improvements prior to 1927 (dates unknown) were included in the acreage total for this period, column two, and taken into account in the percentage figures for this and later periods, column three.

to only 8 per cent of the area of the county.

When Thompson & Hunt made their collections in 1928, 74 per cent of the county was in drainage districts. By 1959, 82 per cent of the county (520,100 acres) had received drainage improvements. Of the 18 per cent of the county remaining, probably a considerable proportion has adequate natural drainage or is in non-agricultural use. Future drainage probably will consist mostly of maintenance and improvement of existing systems.

Dredging to increase the water-carrying capacity of existing streams, or to create ditches in the undrained marshy areas where none existed, eliminated areas of standing water and created new channels. Recanalization of natural streams resulted in much straightening, in the erection of high earthen banks along the sides, in producing greater uniformity of the stream environments, and in drastically altering local habitats, fig. 11.

Subsurface drain tiles reduced areas of standing water and in some places resulted in burying what had been surface drainage courses. As a result, many small, intermittent streams have been replaced by field tiles or by wide, carefully graded grass waterways.

Draining and dredging, which have reduced the water storage capacity of the watershed, have contributed to higher flood levels and lower drought levels in the streams. These practices have lowered the water table and affected the permanency of many small streams. Since the early 1870's, work has been directed toward improving the drainage in Champaign County; in the future this objective may need considerable modification as demands for water supplies increase and efforts are made to hold water to meet these demands.

Some stream courses have been altered. Slight changes in drainage boundaries can be seen on the upper reaches of Hayes Creek, Copper Slough, Camp Creek, the Salt Fork above Rantoul, and the headwaters of the Little Vermilion system.

Two stations where Thompson & Hunt seined, one in a small tributary of the East Branch of the Salt Fork about 3 miles southeast of Rantoul, and one in a tributary of Hayes Creek on the Champaign-Douglas county line, were no longer extant in 1959. They had been replaced by grass waterways. Near St. Joseph, the Salt Fork had been straightened, leaving a large oxbow at the west edge of town. Numerous small streams visited in 1928 by Thompson & Hunt were completely dry in the summer of 1959, due probably to the dry summer rather than to modifications by man or to long-term natural changes.

Some stream changes, including new channels and new meanders, were natural. Such changes as occurred in the county between the mid-1870's (shown in red) and the mid-1950's (shown in black) can be detected in fig 6.

STREAM HABITATS

Most Champaign County streams originate at drain tiles, fig. 7, on the slopes of moraines, or in flat, marshy areas. They flow through straight, usually man-made ditches in rich farmland and move on into less disturbed channels as they become larger and their valleys widen. Certain general ecological characteristics are common to these streams and can be used to distinguish and describe several stream habitats.

General Ecological Characteristics

In Champaign County, the relatively flat topography, the lack of rock outcrops, the similarity of soil materials, and the intensive land-use practices produce an unusual amount of uniformity in the stream environment.

The stream gradient is generally low, usually between 3 and 4 feet of fall per mile. Only on the slopes of moraines and in a few short stretches does it exceed 6 feet per mile. The flow is generally moderate to sluggish during normal water stages. Riffles are gentle and pools are rather shallow. There are long stretches of very uniform depth and flow.

Water levels fluctuate rapidly and drastically. Flooding occurs with some regularity, particularly during the spring and early summer. At normal water stages, streams have levels well within their steep-sided banks. During flood stages, the water levels may rise 10 to 15 feet and temporarily become torrents that erode away stream banks. Within the county, the Sangamon, Salt Fork, Middle Fork, and to a lesser degree the Embarrass rivers have narrow floodplains, which may be completely inundated during floods. Severe dry periods occur nearly every year, usually during August and September. The flow may decrease drastically or even cease. The small headwater tributaries suffer most regularly and severely from dry weather conditions.

Water temperatures in small, shallow, stagnant pools may approach 100 degrees F. during the summer and 32 degrees in the winter. There are no large springs to moderate water temperatures. The lack of shading bank vegetation along shallow areas allows extreme daily fluctuations of temperature, which, in summer, may change as much as 20 degrees F. between the cool morning hours and the hot mid-afternoon. In winter, temperatures may drop sufficiently to freeze the water to the stream bottom in shallow areas. Because fish generally concentrate in deep pools, they are seldom caught in the ice.

The distribution of bottom materials, formed from the basic glacial till, is directly related to the velocity of the water. Through selective sorting of the basic materials, rubble and gravel (the heaviest materials) pile up in riffle areas, sand in areas of moderate current, and the finer particles of silt and clay drop out only in the quiet waters of the deep pools.

Turbidity is generally high, becoming low only during the cold months, when the activity of fish is reduced so much that it does not roil silt on the bottom and when streams are said to be "winter clear." During the field work for the present study, turbidity ranged between 15 and 150 parts per million (p.p.m.).

The chemistry of stream water, basically related to the mineral composition of the watershed, may be strongly influenced by domestic and industrial pollution, table 3. Water in the lower Embarrass, Kaskaskia, Spoon, and Sangamon rivers, which are relatively unpolluted, is low in ammonium, phosphate, and nitrate, in comparison with water from the polluted areas in the Salt Fork River. Hardness (as calcium carbonate content) ranges from 264 to 436 p.p.m. The pH is slightly

Table 3.—Partial chemical analysis of water collected from seven stream locations in Champaign County on December 29, 1960. The streams were mostly ice covered and at normal water level. Temperatures of samples ranged from 32 to 34 degrees F. The water had no measurable color or odor. Turbidity was less than 24 p.p.m. Analysis was made by the Illinois Water Survey. All figures are for p.p.m.

Station	Ammonium	Nitrate	Phosphate	Chloride	Sulfate	Silica	Alkalinity (as $CaCO_3$)	Hardness (as $CaCO_3$)	Total Dissolved Minerals	Alkyl Benzene Sulfonate
Embarrass North of Villa Grove	0.2	2.8	0.1	13	111.7	8.7	284	392	477	0.0
Sangamon Northeast of Mahomet	0.3	5.8	0.0	32	115.0	4.5	304	428	555	0.1
Kaskaskia West of Parkville	tr.	6.5	0.5	7	19.1	11.4	303	264	370	0.1
Spoon River North of St. Joseph	0.5	2.4	0.1	13	152.6	10.4	320	436	555	0.0
East Branch North of St. Joseph	7.4	18.2	13.1	255	85.6	14.0	292	372	850	0.7
West Branch East of Urbana	7.5	14.9	47.4	100	193.2	14.4	360	376	842	1.2
Salt Fork Northwest of Homer	4.8	15.9	22.2	116	107.2	15.0	312	336	705	0.9

above neutral, most of the readings ranging from 7.2 to 7.8. The amount of dissolved oxygen varies from supersaturation in well-aerated riffle areas to less than 1 p.p.m. in highly polluted waters and in stagnant pools when the stream flow is discontinuous.

Much of the natural aquatic vegetation in Champaign County streams may have been eliminated early in this century through dredging, pollution, and other man-induced alterations. The remaining vegetation is limited in distribution by the generally high turbidity of the streams.

Baker (1922) illustrated many of the stream habitats along the Salt Fork as they appeared in 1919 and 1920. Except for a large patch (which no longer exists) of yellow water lillies, *Nuphar advena,* northeast of Sidney, the vegetation seen in his photographs is similar to that found at present. Moreover, his description of the aquatic vegetation includes essentially the same species that now occur in the area.

Thompson & Hunt listed the common coarse aquatic plants that they observed. Their list includes most of the present vegetation. They listed four species of *Potamogeton* that we did not find associated with the flowing waters of the county; however, we observed another species of *Potamogeton,* believed to be *P. foliosus* Rafinesque, in a number of streams and found it to be quite common in the upper reaches of Lone Tree Creek near Foosland. The field notes of Thompson & Hunt and our observations indicate that aquatic vegetation was more extensive in 1928 than it is today.

Dr. Robert A. Evers, of the Section of Applied Botany and Plant Pathology of the Natural History Survey, examined plants in several collections we made during the present study. His identifications add the following species to the list presented by Thompson & Hunt:

Equisetum arvense Linnaeus
Spartina pectinata Link
Carex cristatella Britton
Salix interior Rowlee
Rumex altissimus Wood
Rorippa islandica (Oeder) Borbas
Lysimachia nummularia Linnaeus
Asclepias incarnata Linnaeus
Phyla lanceolata (Michaux) Greene
Lycopus americanus Muhlenberg
Eupatorium perfoliatum Linnaeus
Hibiscus militaris Cavanilles

These plants are not true aquatics but are characteristically associated with the banks and mud flats along most of the streams. A few true aquatics deserve special comment. *Potamogeton foliosus* has already been mentioned as quite common in part of Lone Tree Creek. *Elodea canadensis* Michaux occurs in large patches in the polluted West Branch between Urbana and St. Joseph. *Dianthera americana* Linnaeus is abundant on the riffles and along the shores of many streams, especially in the Middle Fork. *Chara* sp. was taken near a seepage spot on a tributary of the Spoon River near Flatville.

The vegetation we observed in our study included grasses, sedges, ragweeds, milkweeds, docks, and several composites along the small streams as they passed through flat and open farmlands. In some of the reaches of these streams, willows and scrubby growths of a few other deciduous trees overhung the water. Tall deciduous trees lined the banks of most of the large streams. Especially common were silver maple, American elm, cottonwood, sycamore, and willows. In open areas, where the sunshine reached the water, grew buttonbush, rose mallow, water willow, and a few other plants.

Habitat Types

Although the general ecological characteristics of the streams of Champaign County are rather uniform, each stream contains several distinct habitats. The habitats are determined largely by stream size, stream topography and gradient, soil materials comprising the bottom, and human modification of the stream and its drainage basin.

Thompson & Hunt (1930:34–9) classified stream habitats according to size of area drained, permanency, depth, width, current, type of substrate, amount of vegetation and debris, turbidity, and faunal composition. They recognized vernal rivulets; kettle holes at mouths of tile drains; oxbow ponds along small streams; permanent headwater streams; stretches of shallow, sluggish water; gravelly and sandy riffles and stretches; rocky rapids

Table 4.—Champaign County stream habitats, the extent of their occurrence, and their physical characteristics.

Habitat	Miles in County	Drainage Area (Square Miles)	Average Gradient (Feet per Mile)	Maximum Depth (Range in Inches)	Current
Rivulet and small creek	189	10	7	1–10	Variable
Large creek	176	10–200	3	.....	.....
Riffle					
Sand and fine gravel	.....	.....	.....	1–12	Swift
Gravel and boulder	.....	.....	.....	1–12	Swift
Pool					
Shallow	.....	.....	.....	4–24	Moderate
Deep	.....	.....	.....	24–48	Sluggish
Small river	58	200–400	2	.....	.....
Riffle					
Sand and gravel	.....	.....	.....	3–18	Swift
Boulder and rubble	.....	.....	.....	3–18	Swift
Pool					
Shallow	.....	.....	.....	18–36	Moderate
Deep	.....	.....	.....	36–96	Sluggish

and riffles; moderately deep, smoothly flowing stretches; and long, deep pools. They described each habitat and listed characteristic species of fishes.

We prefer a classification based on the same ecological characteristics but having divisions with more easily definable limits, table 4.

Rivulets and Small Creeks.—Our rivulets and small creeks include the vernal rivulets of Thompson & Hunt and also intermittent streams of slightly greater size. They arise as small open gullies coming off the face of moraine slopes, as seeps in grass waterways, or as discharges at field tiles, fig. 7, draining flat marshy areas. The type that originates at a field tile may have an unusual beginning because of the large, and sometimes surprisingly deep, hole that is scoured out at the base of the tile. In many cases, the pool contains a large concentration of fish.

Most rivulets and small creeks in Champaign County have been modified by dredging and straightening of the chan-

Fig. 7.—Drain tile mouth and pool on the East Branch of the Salt Fork of the Vermilion River. A tile mouth is Champaign County's analogue of a spring.

nel. They consist of a long open ditch, flowing smoothly over a substrate of clay, silt, or loam. They lack aquatic vegetation but are bordered by grasses, herbs, and shrubs. Although they include occasional water pockets that could be termed pools, and occasional shallow areas where there is an accumulation of sand and gravel suggesting riffles, their distribution of fishes is relatively uniform throughout. These long open ditches may partially dry up if water flow ceases during the summer months. Their small size, instability of flow, and lack of shade produce a highly unstable aquatic environment.

Large Creeks.—The streams we classify as large creeks are formed by the confluence of the rivulets and small creeks. The water contributed by the network of tributaries is of such volume that flow is continuous throughout most years, although the actual volume may fluctuate drastically from wet to dry seasons. Typically, the large creeks consist of alternating pools, shallow stretches, and riffles (frontispiece). They contain a greater variety of habitats than do rivulets and small creeks. The frequency of occurrence of riffles depends upon the distribution of glacial drift materials, the extent of dredging, and the stream gradient. Some of the large creeks in Champaign County have been dredged; they now have straight rather than meandering courses, a monotonous sameness of environment, and nearly uniform depth, fig. 8.

In the large creeks, riffles over sand and fine gravel are usually without aquatic vegetation; those over gravel and small boulders have some attached algae. Some pools are shallow and have a moderate flow over clay, sand, and silt; they have a variety of aquatic vegetation. Other pools are quiet and deep, having been formed by obstructions or unusual erosion of the bottom materials; they have accumulations of silt and only marginal vegetation. Long, shallow pools make up large proportions of most of the Champaign County streams we have classified as large creeks, fig. 11.

Small Rivers.—The largest streams in the county, hardly larger than creeks

Fig. 8.—The Kaskaskia River southwest of Parkville. This stream, dredged from time to time, illustrates one of the large creek habitats found in Champaign County. Modification of this creek resulted in an unusual amount of sand in the stream bed.

Fig. 9.—Upper picture: a shallow pool in the Sangamon River near Fisher. Habitats such as this contain several species of suckers, basses, and sunfishes, and many species of small fishes. Lower picture: a deep pool in the Salt Fork near Homer. Habitats such as this contain carp, catfish, shad, and relatively few species of small fishes.

by some standards, we have classed as small rivers, figs. 2 and 3. They include the lower Sangamon, the lower Salt Fork, and the Middle Fork. They are permanent streams that have less extreme and less sudden fluctuations in water level and temperature than creeks. Their floodplains and banks are generally shaded by large trees, fig. 9. Like large creeks, the small rivers contain both riffle and pool habitats, table 4.

Riffles of small rivers differ from those of creeks in their greater volume of flow and their greater proportion of large-sized bottom materials. Because of the low gradient of the small rivers, the riffles in these streams are relatively fewer in number and occupy a smaller proportion of the total water area than do those in creeks. Sand and fine gravel riffles with little aquatic vegetation occur in small rivers as well as creeks; because sand and fine gravel occur also in many boulder and rubble riffles that have some aquatic vegetation, the two types of riffles are less clearly defined in rivers than in creeks.

Pools in small rivers are either shallow and have moderate water flow, or deep and have sluggish current, fig. 9. Their characteristics are similar to those of large creeks, but the pools are deeper and have more overhanging vegetation and greater silt deposits. In certain parts of the lower Salt Fork and lower Sangamon, occasional pools are quite deep and have very sluggish water movements.

Other Aquatic Habitats. — Other Champaign County aquatic habitats that do not fit into the above classification are nonstream habitats, such as farm ponds, artificial lakes, and oxbows. No natural lakes and no permanent swamps and marshes remain in the county. Ponds and artificial lakes are of little interest in the present study inasmuch as they have been stocked, and they are of concern only if the fishes they contain spill over into the streams. Oxbows have characteristic lacustrine populations. The component species obviously were derived from the streams with which the oxbows were once associated.

Changes in Stream Habitats

The environment of a stream is sensitive to almost any activity within the watershed. It is influenced by the human population, agriculture, and industry as outlined previously in this paper.

For the 30-year period between the studies of Forbes & Richardson and those of Thompson & Hunt, specific measurements or observations of the stream environment were limited to some studies of stream-flow measurements and draining activities. From these studies and the information on the general development of the county, we know that many water habitats were actually eliminated and that draining and dredging resulted in increased fluctuation of water levels, increased turbidity, and a reduction in aquatic vegetation. We know that channel straightening, with the elimination of meanders, actually shortened stream courses in many areas and consequently increased the stream gradient. The replacement of stagnant-water marshes by underground drains that discharge waters that are relatively cool in summer and warm in winter may have reduced seasonal fluctuations of stream temperatures.

Between the investigations of Thompson & Hunt in 1928 and the present time, we have specific information on certain changes that have occurred. Thompson & Hunt's original field notes provide an unusual opportunity for evaluating various changes in habitats at identical, or nearly identical, collecting sites, figs. 10 and 11. Habitat differences can be seen at specific sites described by Thompson & Hunt and then examined 30 years later during the 1959 investigation. These differences have been evaluated and summarized in table 5.

The principal changes noted have to do with dimensions, particularly in average depth and average width of the pools where collections were made. The field work of the 1928 survey was carried on "from early spring to late autumn" (Thompson & Hunt 1930:14); most of our collections were concentrated in the dry months of late summer. The entire summer of 1959 was considerably drier than that of 1928. Despite differences in the time of field work and in the amount of precipitation in 1928 and 1959, the two censuses disclosed that measurable changes had taken place in the Champaign County drainage systems in the years between the censuses, table 5.

Fig. 10.—The Sangamon River near Mahomet in the autumn of 1928 (above) and the autumn of 1962 (below). The habitats at this site have remained relatively unchanged.

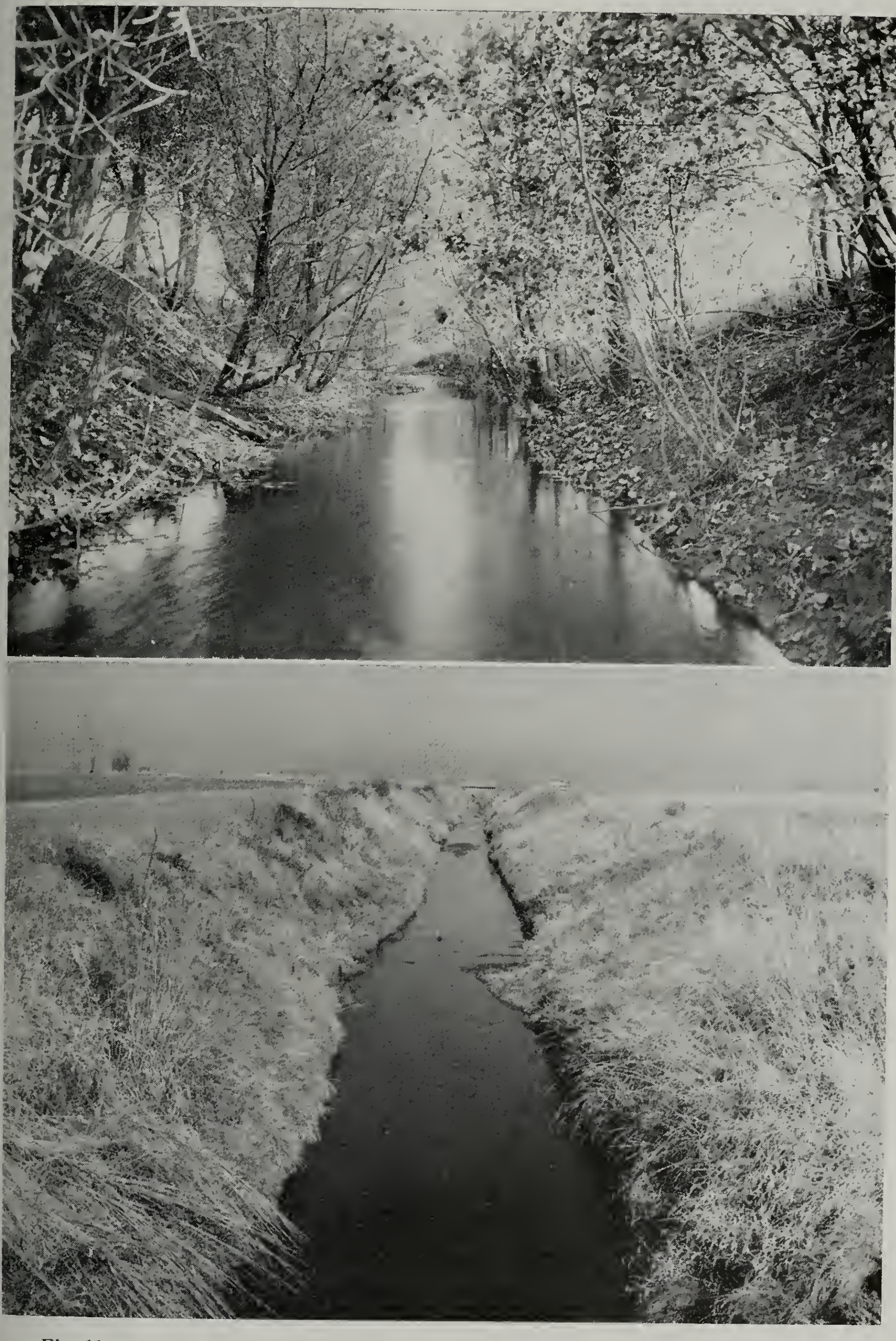

Fig. 11.—The Kaskaskia River near Bondville in the autumn of 1928 (above), some years after it had been dredged, and in the autumn of 1962 (below), after another dredging. Here the Kaskaskia is classed as a large creek.

Table 5.—Changes in stream habitat characteristics of various Champaign County drainages as indicated by the percentage of stations that showed a decrease (—), the percentage that remained the same (0), and the percentage that showed an increase (+) in each of these characteristics between the Thompson & Hunt study in 1928 and the 1959 study. Only those stations are included for which most of the habitat data are available.

Drainage	Number of Stations	Depth			Width			Gravel			Sand			Silt			Aquatic Vegetation			Over-hanging Vegetation			Velocity		
		—	0	+	—	0	+	—	0	+	—	0	+	—	0	+	—	0	+	—	0	+	—	0	+
Sangamon	25	52	40	8	16	48	36	52	48	0	0	48	52	0	48	52	4	96	0	20	76	4	20	76	4
Kaskaskia	11	73	27	0	0	36	64	64	36	0	0	36	74	74	36	0	9	82	9	36	55	9	0	0	100
Embarrass	10	30	70	0	10	60	30	10	90	0	0	90	10	0	90	10	30	60	10	0	90	10	0	100	0
Salt Fork	20	35	55	10	15	40	45	25	75	0	0	75	25	0	75	25	30	55	15	15	65	20	0	95	5
Middle Fork	5	40	60	0	20	20	60	80	20	0	0	20	80	0	20	80	20	80	0	0	60	40	0	100	0

All of the Champaign County drainage systems showed a decided trend toward a decrease in depth and an increase in width, table 5. All of them showed a decrease in gravel and an increase in sand. All but the Kaskaskia River showed an increase in silt, which had covered the gravel or sand present in 1928. In the Kaskaskia, however, sand deposits had covered over both the gravel and silt formerly recorded, fig. 8. A general decrease was evident in the occurrence of aquatic vegetation; an increase had occurred, except along the Sangamon and Kaskaskia rivers, in the amount of overhanging vegetation. Only in the Kaskaskia was there a striking change in water velocity, an increase caused by recent dredging and straightening of the river and perhaps by the introduction of large volumes of well water in its upper reaches. Except for the general increase in width and the unusual conditions cited for the Kaskaskia River, the changes noted were precisely those which could be expected in view of the changes in land use and landscape appearance outlined earlier. Study of the values in table 5 for decrease, unchanged status, and increase for each characteristic in each drainage system reveals the degree of these changes.

ANNOTATED LIST OF FISHES

Ninety species are included in our annotated list of the fishes of Champaign County. One of these, *Hybopsis aestivalis*, is questionable for reasons given subsequently. A few other species, not in the annotated list, are known from streams in adjacent counties and may eventually be found in this county. These species of hypothetical occurrence are *Carpiodes carpio carpio* (Rafinesque), *Moxostoma carinatum* (Cope), *Stizostedion canadense* (Smith), all of which have been taken a short distance downstream in the Salt Fork of the Vermilion in adjacent Vermilion County, and *Etheostoma camurum* (Cope), taken in the Middle Fork of the Vermilion in Vermilion County. A few other species, reported by Champaign County fishermen but not examined by us or documented by specimens, have not been included in our list. Of the 90 species in the annotated list, 74 were taken during 1959 or have been taken since.

The fishes have an unusually complex synonymy. Accordingly, in the following list, the name applied to a Champaign County species by earlier authors is given in every case where the current name differs from that in the literature. In several cases, the "species" of earlier investigators were composites of two or more species as now recognized. Because of these composite species, most of the existing specimens in the Thompson & Hunt collections and a few in the Forbes & Richardson collections have been re-examined and reidentified.

A summary of collections for all three surveys is given. FR refers to Forbes & Richardson, TH to Thompson & Hunt, and LS to Larimore & Smith. The number following the initials designates the number of localities represented; the term "all drainages" following a number indicates that all drainage systems of Champaign County were represented. A "?" following FR or TH indicates some doubt as to whether the species involved was included in the nominal species of Forbes & Richardson (1908) or Thompson & Hunt (1930). Names of drainages from which species were collected are given in parentheses.

Amiidae

Amia calva Linnaeus. Bowfin.—Several large adults taken by rowboat shocker from Kaufman's Clear Lake, where they had been introduced for sport fishing. LS 1 (Kaskaskia).

Lepisosteidae

Lepisosteus osseus (Linnaeus). Longnose gar.—A large adult taken by rowboat shocker in the Middle Fork where it leaves the county. The species was probably missed by earlier investigators because of its rarity in the county. LS 1 (Middle Fork).

Hiodontidae

Hiodon alosoides (Rafinesque). Goldeye.—One specimen known from Champaign County. This specimen, taken on the Kaskaskia River at the lowermost station in the county and reported as *Hiodon tergisus* by Thompson & Hunt, is still extant and is reidentified as *H. alosoides.* TH 1 (Kaskaskia).

Clupeidae

Dorosoma cepedianum (Le Sueur). Gizzard shad.—FR 3 (Kaskaskia), TH 2 (Sangamon), LS 12 (Embarrass, Salt Fork, Sangamon).

Esocidae

Esox americanus vermiculatus Le Sueur. Grass pickerel.—Reported as *Esox vermiculatus* by Forbes & Richardson, Thompson & Hunt, and other early authors. FR 10 (Kaskaskia, Salt Fork, Middle Fork, Sangamon), TH 26 (Kaskaskia, Embarrass, Little Vermilion, Salt Fork, Sangamon), LS 17 (all drainages).

Catostomidae

Carpiodes cyprinus hinei Trautman. Central quillback carpsucker.—Reported as *Carpiodes velifer* by Forbes & Richardson, Thompson & Hunt, and other early authors. FR 10 (Salt Fork, Middle Fork, Sangamon), TH 9 (Middle Fork, Sangamon), LS 27 (Salt Fork, Middle Fork, Sangamon).

Carpiodes velifer (Rafinesque). Highfin carpsucker.—Reported as *Carpiodes difformis* by Forbes & Richardson, Thompson & Hunt, and other early authors. FR 8 (Kaskaskia, Salt Fork, Middle Fork, Sangamon), TH 4 (Middle Fork, Sangamon), LS 9 (Salt Fork, Middle Fork, Sangamon).

Catostomus commersoni commersoni (Lacépède). White sucker.—FR 14 (Salt Fork, Middle Fork, Sangamon), TH 63 (not 65 as stated: all drainages), LS 76 (all drainages except Little Vermilion).

Erimyzon oblongus claviformis (Girard). Western creek chubsucker.—Reported as *Erimyzon sucetta oblongus,* a composite of *E. sucetta* and *E. oblongus,* by Forbes & Richardson, Thompson & Hunt, and other early authors. There is no evidence that *E. sucetta* ever occurred within the county, although it is known from deep quarries in adjacent Vermilion County. FR 22 (all drainages except Little Vermilion), TH 43 (all drainages), LS 79 (all drainages).

Hypentelium nigricans (Le Sueur). Northern hog sucker.—Reported as *Catostomus nigricans* by Forbes & Richardson, Thompson & Hunt, and other early authors. FR 7 (Salt Fork, Middle Fork, Sangamon), TH 27 (all drainages except Little Vermilion), LS 42 (all drainages except Little Vermilion).

Ictiobus bubalus (Rafinesque). Smallmouth buffalo.—A single specimen taken on the lower Sangamon River. FR 1 (Sangamon).

Ictiobus cyprinellus (Valenciennes). Bigmouth buffalo.—One specimen reported from the lower Sangamon. TH 1 (Sangamon).

Ictiobus niger (Rafinesque). Black buffalo.—Reported as *Ictiobus urus* by Thompson & Hunt and known in the county by a single specimen taken on the lower Sangamon River. TH 1 (Sangamon).

Minytrema melanops (Rafinesque). Spotted sucker.—FR 15 (Kaskaskia, Salt Fork, Middle Fork, Sangamon), TH 4 (not 5 as stated: Kaskaskia, Salt Fork), LS 1 (Little Vermilion).

Moxostoma anisurum (Rafinesque). Silver redhorse.—TH 1 (Sangamon), LS 7 (Salt Fork, Sangamon).

Moxostoma macrolepidotum macrolepidotum (Le Sueur). Northern redhorse.—Reported as *Moxostoma breviceps* by Forbes & Richardson, Thompson & Hunt, and other early authors, but later and until very recently called *M. aureolum.* FR 1 (Salt Fork), TH 6 (Kaskaskia, Sangamon), LS 8 (Sangamon).

Moxostoma erythrurum (Rafinesque). Golden redhorse.—Reported as *Moxostoma aureolum* by Forbes & Richardson, Thompson & Hunt, and other early authors, who presumably based their identifications on specimens of this species. The superficially similar *M. duquesnei*, which the early authors did not distinguish from *erythrurum,* was not taken in the county during the 1959 survey and is not represented among the Forbes & Richardson and Thompson & Hunt collections still extant. FR 11 (Salt Fork, Middle Fork, Sangamon), TH 22 (all drainages except Little Vermilion), LS 28 (Embarrass, Salt Fork, Middle Fork, Sangamon).

Cyprinidae

Campostoma anomalum pullum (Agassiz). Central stoneroller.—Reported as *Campostoma anomalum* by Forbes & Richardson, Thompson & Hunt, and other early authors. This fish is assignable to the subspecies *C. a. pullum.* FR 17 (Salt Fork, Middle Fork, Sangamon), TH 64 (all drainages except Little Vermilion), LS 102 (all drainages except Little Vermilion).

Carassius auratus (Linnaeus). Goldfish.—Several large specimens taken by rowboat shocker from Kaufman's Clear Lake, where they had been introduced. Another adult was found in the Salt Fork near Homer in 1955. LS 2 (Kaskaskia, Salt Fork).

Cyprinus carpio Linnaeus. Carp.—FR 4 (Salt Fork, Middle Fork, Sangamon), TH 11 (not 9 as stated: Embarrass, Salt Fork, Sangamon), LS 56 (all drainages).

Ericymba buccata Cope. Silverjaw minnow.—FR 22 (Kaskaskia, Salt Fork, Embarrass, Middle Fork), TH 79 (all drainages), LS 78 (all drainages except Little Vermilion).

Hybognathus nuchalis nuchalis Agassiz. Western silvery minnow.—FR 4 (Salt Fork, Middle Fork, Sangamon), TH 9 (Kaskaskia), LS 9 (Kaskaskia).

Hybopsis aestivalis hyostoma (Gilbert). Ohio speckled chub.—Reported from the Middle Fork on the Champaign-Ford county line as *Hybopsis hyostomus* by Large (1903:19). The locality, which is far removed from other records of the species, was either ignored or overlooked by Forbes & Richardson and Thompson & Hunt; inasmuch as Large's specimen is not extant for reidentification and additional specimens have never been taken, the record is open to doubt.

Hybopsis amblops amblops (Rafinesque). Northern bigeye chub.—FR 6 (Salt Fork, Middle Fork), TH 8 (Embarrass, Salt Fork, Middle Fork).

Hybopsis biguttata (Kirtland). Hornyhead chub.—Reported as *Hybopsis kentuckiensis* by Forbes & Richardson, Thompson & Hunt, and other early authors. FR 10 (Salt Fork, Middle Fork, Sangamon), TH 46 (Kaskaskia, Middle Fork, Sangamon), LS 70 (Kaskaskia, Salt Fork, Middle Fork, Sangamon).

Hybopsis storeriana (Kirtland). Silver chub.—A specimen from the Middle Fork reported by Forbes & Richardson. A second specimen, an individual 4.5 inches long taken on a hook in the Salt Fork River near Homer in July, 1952, was reported to us by Dr. Marcus S. Goldman. FR 1 (Middle Fork), LS 1 (Salt Fork).

Notemigonus crysoleucas (Mitchill). Golden shiner.—Reported as *Abramis crysoleucas* by Forbes & Richardson, Thompson & Hunt, and other early authors. FR 20 (Kaskaskia, Salt Fork, Middle Fork, Sangamon), TH 41 (all drainages), LS 46 (all drainages).

Notropis amnis amnis Hubbs & Greene. Northern pallid shiner.—Specimens of this species referred by Thompson & Hunt (on different pages) to *Notropis heterolepis, N. cayuga,* and *N. c. atrocaudalis.* One of their specimens was subsequently designated as a paratype of the new species *amnis.* A re-examination of the Thompson & Hunt specimens of *"Notropis blennius"* still extant has revealed specimens of *amnis* mixed with *N. stramineus* from three stations on the Sangamon near Fisher. TH 3 (Sangamon).

Notropis atherinoides atherinoides Rafinesque. Common emerald shiner.—FR 2 (Salt Fork, Sangamon), LS 2 (Embarrass, Salt Fork).

Notropis boops Gilbert. Bigeye shiner. —Reported as *Notropis illecebrosus* by Forbes & Richardson, Thompson & Hunt, and other early authors. FR 1 (Salt Fork), TH 2 (Middle Fork).

Notropis chrysocephalus (Rafinesque). Central common shiner.—Reported as *Notropis cornutus* by Forbes & Richardson, Thompson & Hunt, and other early authors. FR 9 (Salt Fork, Sangamon), TH 54 (Kaskaskia, Salt Fork, Middle Fork, Sangamon), LS 64 (all drainages except Little Vermilion).

Notropis dorsalis dorsalis (Agassiz). Central bigmouth shiner.—Reported as *Notropis gilberti* by Forbes & Richardson, Thompson & Hunt, and other early authors. FR 1 (Salt Fork), TH 5 (Sangamon), LS 28 (Kaskaskia, Middle Fork, Sangamon).

Notropis heterolepis Eigenmann & Eigenmann. Blacknose shiner.—Reported as *Notropis cayuga* and *N. c. atrocaudalis* by Forbes & Richardson. Their records for the Salt Fork and Sangamon drainages presumably refer only to the blacknose shiner. The species may have disappeared from the county when the prairie sloughs and natural lakes were drained. The specimen assigned to *N. heterolepis* by Thompson & Hunt is actually *N. amnis amnis.* FR 2 (Salt Fork, Sangamon).

Notropis lutrensis (Baird & Girard). Red shiner.—A species appearing in the county since 1928. It is now abundant in the Kaskaskia and upper Sangamon drainages in a variety of river and creek habitats. LS 21 (Kaskaskia, Sangamon).

Notropis rubellus (Agassiz). Rosyface shiner.—Misidentified as *"Notropis atherinoides,* var." by Thompson & Hunt. Our collections from the same stations contain *rubellus* and not *atherinoides.* Of the three Thompson & Hunt collections labeled *atherinoides,* the one extant contains *rubellus* only. TH 3 (Middle Fork), LS 6 (Middle Fork).

Notropis spilopterus spilopterus (Cope) × *hypsisomatus* Gibbs. Spotfin shiner.—Included in the composite *Notropis whipplii* of Forbes & Richardson, Thompson & Hunt, and other early authors. Of the 53 collections of *"N. whipplii"* reported by Thompson & Hunt, 34 are still extant and have been reidentified. Thirty-two of these contain spotfin shiners. Material from the eastern side of the county (Salt Fork and Middle Fork) is assignable to the nominate subspecies on the basis of both lateral-line scale counts and body shape, specimens from the Kaskaskia (western side) are apparently typical *hypsisomatus* in both characters, and specimens from the Sangamon (western side) have nearly typical lateral-line scale counts of *hypsisomatus* but are intermediate between *spilopterus* and *hypsisomatus* in body shape. FR ?, TH 32 (Kaskaskia, Salt Fork, Middle Fork, Sangamon), LS 63 (all drainages).

Notropis stramineus (Cope). Sand shiner.—Included in the composite *Notropis blennius* of Forbes & Richardson, Thompson & Hunt, and other early authors, but until recently called *N. deliciosus.* The identity of the Forbes & Richardson specimens is not known, but probably the majority belong to this species. Of the 44 collections of *"blennius"* reported by Thompson & Hunt, 32 are still extant and have been reidentified, revealing *stramineus* exclusively, or in part, in all of them. FR ?, TH 32 (all drainages except Little Vermilion), LS 93 (all drainages).

Notropis umbratilis cyanocephalus (Copeland). Redfin shiner.—Reported as *Notropis umbratilis atripes* by Forbes &

Richardson, Thompson & Hunt, and other early authors. Local populations are extremely variable, and subspecific identification is based on geographical grounds. FR 8 (Salt Fork, Sangamon), TH 69 (all drainages), LS 97 (all drainages).

Notropis volucellus volucellus (Cope). Northern mimic shiner.—Probably included in the composite *Notropis blennius* of Forbes & Richardson and found in 2 collections (representing two localities) in the 32 reidentified collections still extant of Thompson & Hunt's "*N. blennius.*" FR ?, TH 2 (Middle Fork), LS 3 (Middle Fork, Sangamon).

Notropis whipplei (Girard). Steelcolor shiner.—Probably included in the composite *Notropis whipplii* of Forbes & Richardson and found at 16 localities in the 34 reidentified collections of Thompson & Hunt's "*whipplii.*" FR ?, TH 16 (Kaskaskia, Embarrass, Salt Fork, Middle Fork, Sangamon), LS 27 (Embarrass, Salt Fork, Middle Fork, Sangamon).

Opsopoeodus emiliae Hay. Pugnose minnow.—A specimen from the Salt Fork reported by Large (1903:15). TH 2 (Kaskaskia; 1 reported from a tributary and another found among a series of Thompson & Hunt's "*Notropis blennius*" from the Kaskaskia proper).

Phenacobius mirabilis (Girard). Suckermouth minnow.—FR 18 (Kaskaskia, Embarrass, Salt Fork, Sangamon), TH 25 (Kaskaskia, Salt Fork, Middle Fork, Sangamon), LS 34 (all drainages except Little Vermilion).

Pimephales notatus (Rafinesque). Bluntnose minnow.—FR 37 (all drainages except Little Vermilion), TH 111 (all drainages), LS 134 (all drainages).

Pimephales promelas promelas Rafinesque. Northern fathead minnow.—FR 4 (Sangamon), TH 19 (Sangamon), LS 20 (Sangamon, Kaskaskia).

Pimephales vigilax perspicuus (Girard). Northern bullhead minnow.—Reported as *Cliola vigilax* by Forbes & Richardson, Thompson & Hunt, and other early authors. FR 6 (Sangamon), TH 4 (Salt Fork, Sangamon).

Semotilus atromaculatus atromaculatus (Mitchill). Northern creek chub.—FR 9 (Salt Fork, Middle Fork, Sangamon), TH 101 (all drainages), LS 126 (all drainages).

Ictaluridae

Ictalurus melas (Rafinesque). Black bullhead.—Reported as *Ameiurus melas* by Forbes & Richardson, Thompson & Hunt, and other early authors. FR 12 (Kaskaskia, Salt Fork, Middle Fork, Sangamon), TH 12 (not 13 as stated: all drainages except Middle Fork), LS 7 (all drainages except Middle Fork).

Ictalurus natalis (Le Sueur). Yellow bullhead.—Reported as *Ameiurus natalis* by Forbes & Richardson, Thompson & Hunt, and other early authors. FR 6 (Kaskaskia, Salt Fork), TH 15 (all drainages except Embarrass), LS 38 (all drainages).

Ictalurus nebulosus (Le Sueur). Brown bullhead.—Taken only from Franzen's Fishing Lake. Many specimens of this species were introduced into this lake for sport fishing during the course of our survey. LS 1 (Salt Fork).

Ictalurus punctatus (Rafinesque). Channel catfish.—FR 4 (Salt Fork, Middle Fork, Sangamon), TH 11 (not 8 as stated: Salt Fork, Sangamon), LS 17 (Salt Fork, Sangamon, Middle Fork).

Noturus exilis Nelson. Slender madtom.—Reported as *Schilbeodes exilis* by Thompson & Hunt. TH 2 (Middle Fork, Sangamon).

Noturus flavus Rafinesque. Stonecat.—FR 1 (Sangamon), TH 5 (Salt Fork, Middle Fork, Sangamon), LS 22 (Salt Fork, Middle Fork, Sangamon).

Noturus gyrinus (Mitchill). Tadpole madtom.—Reported as *Schilbeodes gyrinus* by Forbes & Richardson, Thompson & Hunt, and other early authors. FR 13 (Kaskaskia, Salt Fork, Sangamon), TH 8 (not 7 as stated: Salt Fork), LS 18 (Kaskaskia, Salt Fork, Sangamon).

Noturus miurus Jordan. Brindled madtom.—Reported as *Schilbeodes miurus* by Forbes & Richardson, Thompson & Hunt, and other early authors. FR 2 (Salt Fork), TH 2 (not 1 as stated: Salt Fork), LS 8 (Embarrass, Salt Fork, Middle Fork).

Noturus nocturnus Jordan & Gilbert. Freckled madtom. — A specimen seined from a pool over mixed sand-gravel and another from a fast riffle in the middle Sangamon River. LS 2 (Sangamon).

Pylodictis olivaris (Rafinesque). Flathead catfish.—Reported as *Leptops olivar-*

is by Thompson & Hunt. TH 1 (Sangamon), LS 4 (Middle Fork, Salt Fork, Sangamon). The flathead is probably much more common than the available records indicate.

Anguillidae

Anguilla rostrata (Le Sueur). American eel.—Reported as *Anguilla chrysypa* by Thompson & Hunt on the basis of a specimen caught by a fisherman in the Embarrass River near Villa Grove just south of the Champaign County line. Dr. Marcus S. Goldman informs us that a specimen was taken on baited hook in the lower Sangamon River about 1940. In the spring of 1961, two eels were taken by hook-and-line fishermen from a small land-locked lake near Mahomet. We subsequently learned that these fish, originally from the Wabash River, escaped from the creel of a local fisherman. TH 1 (Embarrass), LS 1 (Sangamon).

Cyprinodontidae

Fundulus notatus (Rafinesque). Blackstripe topminnow.—FR 14 (Kaskaskia, Embarrass, Salt Fork, Sangamon), TH 41 (not 43 as stated: all drainages), LS 54 (all drainages).

Poeciliidae

Gambusia affinis affinis (Baird & Girard). Western mosquitofish.—A recent arrival in the county. LS 2 (Salt Fork).

Atherinidae

Labidesthes sicculus (Cope). Brook silverside.—FR 6 (Salt Fork, Sangamon), TH 5 (not 3 as stated: Salt Fork), LS 3 (Salt Fork).

Aphredoderidae

Aphredoderus sayanus (Gilliams). Pirateperch.—FR 1 (Sangamon), TH 12 (Kaskaskia, Embarrass, Sangamon), LS 13 (Kaskaskia, Embarrass, Sangamon).

Serranidae

Roccus mississippiensis (Jordan & Eigenmann). Yellow bass.—Now known in this county only in Kaufman's Clear Lake and Lake-of-the-Woods, where it has been introduced. The evidence indicates that the yellow bass held a brief tenure in the Sangamon River of Champaign County from 1955 to 1958. Dr. Marcus S. Goldman has numerous yellow bass records for the Sangamon for 1955, and we took specimens there in November of 1957. The Sangamon River fish presumably came from the Lake Decatur population. LS 3 (Kaskaskia, Sangamon).

Centrarchidae

Ambloplites rupestris rupestris (Rafinesque). Northern rock bass.—TH 1 (Salt Fork), LS 16 (Salt Fork, Middle Fork, Sangamon).

Chaenobryttus gulosus (Cuvier). Warmouth.—A specimen taken by us on the Sangamon near Mahomet in November, 1957. Dr. Marcus S. Goldman reports that he has taken the species on hook and line in the same area. FR 3 (Kaskaskia), TH 1 (Salt Fork), LS 1 (Sangamon).

Lepomis cyanellus Rafinesque. Green sunfish.—FR 23 (all drainages except Little Vermilion), TH 38 (all drainages), LS 75 (all drainages except Little Vermilion).

Lepomis humilis (Girard). Orangespotted sunfish.—FR 16 (Kaskaskia, Salt Fork, Middle Fork, Sangamon), TH 13 (Salt Fork, Middle Fork, Sangamon), LS 9 (Salt Fork, Middle Fork, Sangamon).

Lepomis macrochirus macrochirus Rafinesque. Northern bluegill.—Reported as *Lepomis pallidus* by Forbes & Richardson, Thompson & Hunt, and other early authors. FR 2 (Salt Fork, Sangamon), TH 1 (Salt Fork), LS 16 (Kaskaskia, Salt Fork, Sangamon).

Lepomis megalotis megalotis (Rafinesque). Central longear sunfish.—FR 16 (Kaskaskia, Salt Fork, Middle Fork), TH 37 (not 39 as stated: all drainages), LS 44 (all drainages).

Lepomis microlophus (Gunther). Redear sunfish.—Formerly known as *Eupomotis heros*. The widely transplanted redear is a recent arrival in Champaign County. Dr. Marcus S. Goldman recalls catching the species in the Sangamon near the Champaign-Piatt county line in the summer of 1958. LS 1 (Kaskaskia).

Lepomis punctatus miniatus Jordan. Spotted sunfish.—A specimen taken from the outlet of Crystal Lake by Thompson & Hunt and reported as *Lepomis miniatus* (Garman's sunfish). Their specimen is no longer extant. TH 1 (Salt Fork).

Micropterus dolomieui dolomieui Lacépède. Northern smallmouth bass.—FR 1 (Salt Fork), TH 16 (Salt Fork, Middle Fork, Sangamon), LS 37 (Kaskaskia, Salt Fork, Middle Fork, Sangamon).

Micropterus punctulatus punctulatus (Rafinesque). Northern spotted bass.—Probably included in the composite *Micropterus salmoides* of Forbes & Richardson, Thompson & Hunt, and other early authors. Their specimens of *"salmoides"* are not available for re-examination. FR ?, TH ?, LS 9 (Salt Fork, Middle Fork).

Micropterus salmoides salmoides (Lacépède). Northern largemouth bass.—Probably included in the composite *Micropterus salmoides* of Forbes & Richardson, Thompson & Hunt, and other early authors. Their specimens are no longer extant. FR ?, TH ?, LS 14 (Salt Fork, Middle Fork, Sangamon).

Pomoxis annularis Rafinesque. White crappie.—FR 4 (Embarrass, Salt Fork, Sangamon), TH 2 (Sangamon), LS 16 (Kaskaskia, Salt Fork, Middle Fork, Sangamon).

Pomoxis nigromaculatus (Le Sueur). Black crappie.—Reported as *Pomoxis sparoides* by Forbes & Richardson, Thompson & Hunt, and other early authors. FR 7 (Kaskaskia, Salt Fork, Sangamon), TH 3 (Sangamon), LS 2 (Salt Fork, Sangamon).

Percidae

Ammocrypta pellucida (Baird). Eastern sand darter.—TH 2 (Middle Fork), LS 3 (Middle Fork).

Etheostoma asprigene (Forbes). Mud darter.—Reported as *Etheostoma jessiae* by Forbes & Richardson. FR 2 (not 1 as stated by Thompson & Hunt: Salt Fork and Sangamon), LS 1 (Sangamon).

Etheostoma blennioides Rafinesque. Greenside darter.—Reported as *Diplesion blennioides* by Forbes & Richardson, Thompson & Hunt, and other early authors. FR 7 (Salt Fork), TH 10 (Embarrass, Salt Fork, Middle Fork), LS 13 (Embarrass, Little Vermilion, Salt Fork, Middle Fork).

Etheostoma caeruleum Storer. Rainbow darter.—Probably included in the composite *Etheostoma coeruleum* of Forbes & Richardson; seven localities represented among the 11 Thompson & Hunt collections still extant. FR ?, TH 7 (Embarrass, Salt Fork, Middle Fork), LS 7 (Kaskaskia, Embarrass, Salt Fork, Middle Fork).

Etheostoma chlorosomum (Hay). Bluntnose darter.—Reported as *Boleosoma camurum* by Forbes & Richardson, Thompson & Hunt, and other early authors. FR 1 (Sangamon), TH 1 (Kaskaskia).

Etheostoma flabellare flabellare (Rafinesque) × *lineolatum* (Agassiz). Fantail darter.— Champaign County specimens representing an intergrade population. Material from the Sangamon is rather distinctly striped and approaches typical *lineolatum,* whereas *flabellare* influence predominates in our series from the Salt Fork drainage. Specimens from the other drainage systems are intermediate in pattern. FR 2 (Salt Fork), TH 16 (not 14 as stated: Embarrass, Salt Fork, Middle Fork, Sangamon), LS 18 (Salt Fork, Middle Fork, Sangamon).

Etheostoma gracile (Girard). Slough darter.—Reported as *Boleichthys fusiformis* by Thompson & Hunt and known in the county from only one specimen, still extant, taken on lower Wildcat Slough. TH 1 (Sangamon).

Etheostoma nigrum nigrum (Rafinesque). Eastern Johnny darter.—Reported as *Boleosoma nigrum* by Forbes & Richardson, Thompson & Hunt, and other early authors. We assign the Champaign County material to the nominate subspecies on geographical grounds. Material from the Embarrass, Little Vermilion, and perhaps the Kaskaskia is clearly referable to *Etheostoma nigrum nigrum,* but large series from the Sangamon, Salt Fork, and Middle Fork exhibit characters of both *E. n. nigrum* and *E. n. eulepis* Hubbs & Greene, and specimens from the Salt Fork and Middle Fork of the Vermilion display predominantly *eulepis* characters. FR 19 (Embarrass, Salt Fork, Sangamon), TH 82 (all drainages), LS 80 (all drainages).

Etheostoma spectabile spectabile (Agassiz). Northern orangethroat darter.—Probably included in the composite *Etheostoma coeruleum* of Forbes & Richardson and found in 4 of the 11 Thompson & Hunt collections still extant. FR ?, TH 4 (Sangamon), LS 60 (all drainages).

Etheostoma zonale zonale (Cope). Eastern banded darter.—TH 8 (Sangamon), LS 6 (Sangamon).

Percina caprodes caprodes (Rafinesque) × *semifasciata* (De Kay). Logperch.—The meager material available regarded as representing an intergrade population. Middle Fork specimens show greater resemblance to *Percina caprodes semifasciata* and Kaskaskia specimens to *P. c. caprodes;* Sangamon specimens are almost exactly intermediate. FR 2 (Salt Fork, Sangamon), TH 2 (Kaskaskia, Middle Fork), LS 10 (all drainages except the Salt Fork).

Percina maculata (Girard). Blackside darter.—Reported as *Hadropterus aspro* by Forbes & Richardson, Thompson & Hunt, and other early authors. FR 15 (Salt Fork, Sangamon), TH 24 (all drainages except Little Vermilion), LS 49 (all drainages except Little Vermilion).

Percina phoxocephala (Nelson). Slenderhead darter.—Reported as *Hadropterus phoxocephalus* by Forbes & Richardson, Thompson & Hunt, and other early authors. FR 3 (Salt Fork, Sangamon), TH 8 (Salt Fork, Middle Fork, Sangamon), LS 18 (Salt Fork, Middle Fork, Sangamon).

Percina sciera sciera (Swain). Northern dusky darter.—A specimen recently taken in the minnow seine near Penfield, the first record for the county. LS 1 (Middle Fork).

Sciaenidae

Aplodinotus grunniens Rafinesque. Freshwater drum.—TH 3 (Sangamon), LS 4 (Sangamon).

ANALYSIS OF DISTRIBUTION PATTERNS

Of the 90 species of fishes in our annotated list for Champaign County, 7 (*Amia calva, Carassius auratus, Ictalurus nebulosus, Gambusia affinis, Roccus mississippiensis, Lepomis punctatus,* and *Lepomis microlophus*) are introductions and must be excluded from any distributional analysis of native species.

Of the remaining 83 species, 13 reach the edges of their natural ranges within, or very near, Champaign County. They can be classified as northern, southern, western, and eastern components on the basis of the direction in which their main ranges are located in relation to the county. *Notropis rubellus* and *Etheostoma zonale* are northern species that, in Illinois, reach their southernmost point of distribution within the county. *Notropis heterolepis* also is a northern species that once extended southward somewhat below Champaign County, but whose range has since retreated to the north. *Noturus nocturnus, Micropterus punctulatus,* and *Etheostoma gracile* are southern species that, in Illinois, have their northernmost records of occurrence within the county. *Notropis dorsalis, Notropis lutrensis,* and *Noturus exilis* are western species that, in Illinois, reach their easternmost limit of distribution in the county. *Noturus miurus, Etheostoma blennioides,* and *Hybopsis amblops* are eastern species that, at least at this latitude, reach their westernmost limit of distribution in the county. *Ericymba buccata,* another eastern species, occurs throughout Champaign County but does not occur, in central Illinois, much to the west of our area. Peripheral populations are of considerable interest in that they can, when studied over a period of time, provide evidence of range expansion and withdrawal. The 13 species just mentioned above have been carefully studied for such trends, and the data that they provide are discussed under Changes in Distribution.

The other 70 species of fishes in our Champaign County list have more extensive ranges and occur throughout this part of the state. These 70 species, needless to say, do not occur everywhere in the county. In fact, only 19 species are known to occur in all six drainages within the county. These species are as follows:

Esox americanus
Catostomus commersoni
Erimyzon oblongus
Cyprinus carpio
Ericymba buccata
Notemigonus crysoleucas
Notropis spilopterus
Notropis stramineus
Notropis umbratilis
Pimephales notatus
Semotilus atromaculatus
Ictalurus melas
Ictalurus natalis

Fundulus notatus
Lepomis cyanellus
Lepomis megalotis
Etheostoma nigrum
Etheostoma spectabile
Percina caprodes

Certain additional species, such as *Lepomis macrochirus* and *Micropterus salmoides*, are known to be in many ponds in all parts of the county, having been introduced for sport fishing, but they were not taken in all drainages as regular components of the stream populations.

Some species could be expected to show seasonal differences in occurrence, as several of our drainages are represented by headwaters only. For example, some of the catostomids might have been present in headwaters during the spring months but might have migrated downstream and out of the county before our summer field work began. Although our data on seasonal distribution are limited, we found no evidence to support the assumption that spring runs of migratory species greatly influence the occurrence of species in Champaign County. We revisited approximately 20 stations in the county one or more times, the revisits representing the months of September, October, January, May, June, and July. Subsequent visits to a station usually revealed a few species that we missed on the initial visit, but at every station the greatest number of species was taken on the first visit, probably because the low water levels in July and August of 1959 had concentrated the fishes. Moreover, the species added on subsequent visits were usually fishes of relatively sedentary habits rather than strongly migratory species such as catostomids.

CHANGES IN DISTRIBUTION

The earliest published references to Champaign County fishes appear to be those of Large (1903:19, 15), who cited *Hybopsis hyostomus* (equals *H. aestivalis*) and *Opsopaeodus* [sic] *megalops* (equals *Opsopoeodus emiliae*) from specific localities within the county. No date or other information is given, but the collections are presumed to have been made prior to the extensive work of Forbes & Richardson. Both records, although published in 1903, were overlooked, or perhaps ignored, by Forbes & Richardson (1908) and all subsequent authors. The specimens are no longer extant.

Although fish collections by staff members of the Illinois State Laboratory of Natural History, a parent agency of the Natural History Survey, were made as early as 1882, no references to Champaign County fishes, except those by Large (1903:15, 19), appeared until Forbes (1907) published a paper on the distribution of certain Illinois fishes.

Forbes & Richardson Records

The Forbes & Richardson distributional records were plotted on the maps in an atlas accompanying *The Fishes of Illinois* or were cited in the text. Although fish nomenclature of 1908 differs markedly from that of today, we are virtually certain that the following species as now recognized were included in the 48 collections of Forbes & Richardson:

Dorosoma cepedianum
Esox americanus
Carpiodes cyprinus
Carpiodes velifer
Catostomus commersoni
Erimyzon oblongus
Hypentelium nigricans
Ictiobus bubalus
Minytrema melanops
Moxostoma macrolepidotum
Moxostoma erythrurum
Campostoma anomalum
Cyprinus carpio
Ericymba buccata
Hybognathus nuchalis
Hybopsis amblops
Hybopsis biguttata
Hybopsis storeriana
Notemigonus crysoleucas
Notropis atherinoides
Notropis boops
Notropis chrysocephalus
Notropis dorsalis
Notropis heterolepis
Notropis umbratilis
Phenacobius mirabilis
Pimephales notatus
Pimephales promelas
Pimephales vigilax
Semotilus atromaculatus
Ictalurus melas
Ictalurus natalis
Ictalurus punctatus

Noturus flavus
Noturus gyrinus
Noturus miurus
Fundulus notatus
Labidesthes sicculus
Aphredoderus sayanus
Chaenobryttus gulosus
Lepomis cyanellus
Lepomis humilis
Lepomis macrochirus
Lepomis megalotis
Micropterus dolomieui
Pomoxis annularis
Pomoxis nigromaculatus
Etheostoma asprigene
Etheostoma blennioides
Etheostoma chlorosomum
Etheostoma flabellare
Etheostoma nigrum
Percina caprodes
Percina maculata
Percina phoxocephala

In addition to the species cited above are probably others. Forbes & Richardson's nominal *"Notropis blennius"* was probably a composite of *N. stramineus* and *N. volucellus,* their *"Notropis whipplii"* a composite of *N. spilopterus* and *N. whipplei,* their *"Micropterus salmoides"* a composite of *M. punctulatus* and *M. salmoides,* and their *"Etheostoma coeruleum"* a composite of *E. caeruleum* and *E. spectabile.* Although many of the early collections have been lost and cannot be reidentified, we are reasonably certain that 63 species were represented in the collections of Forbes & Richardson and that the 2 other species reported previously by Large (1903:15, 19) bring the total number of species collected in the county by 1901 to 65.

Thompson & Hunt Records

Although the material of Forbes & Richardson was cited in various revisionary studies published between 1901 and 1928, no additional Champaign County records for this period were published in these taxonomic papers.

Thompson & Hunt, in their 1930 publication, chose to use the nomenclature of Forbes & Richardson, and many of their nominal species would have been difficult to assign had we not had much of their material for reidentification. They claimed the addition of 13 species to the known fauna of Champaign County, but restudy of their specimens indicated that they actually added the following 15:

Hiodon alosoides
Ictiobus cyprinellus
Ictiobus niger
Moxostoma anisurum
Notropis amnis
Notropis rubellus
Noturus exilis
Pylodictis olivaris
Ambloplites rupestris
Lepomis punctatus
(probably introduced)
Anguilla rostrata
(from adjacent Douglas County)
Ammocrypta pellucida
Etheostoma gracile
Etheostoma zonale
Aplodinotus grunniens

Their nominal *"Notropis blennius"* included both *N. stramineus* and *N. volucellus;* their *"Notropis whipplii,"* both *N. spilopterus* and *N. whipplei;* and their *"Etheostoma coeruleum,"* both *E. caeruleum* and *E. spectabile.* Whether their *"Micropterus salmoides"* also included *M. punctulatus* is not known, as the specimens have been lost.

Thompson & Hunt believed that they missed only three species that had been previously recorded from the county, whereas they actually failed to rediscover the following six:

Ictiobus bubalus
Hybopsis aestivalis
Hybopsis storeriana
Notropis atherinoides
Notropis heterolepis
Etheostoma asprigene

The discrepancy is due to their apparent misidentification of *Notropis atherinoides* and their failure to include the two species recorded by Large (1903:15, 19). In all, Thompson & Hunt obtained 74 species, 59 of which had been recorded previously from the county.

Almost half of the species recorded by both Forbes & Richardson and Thompson & Hunt showed an increase in number of stations and in number of drainages occupied in the approximately 30-year period between the surveys. Many of the apparent increases in abundance are of doubtful significance because of the more intensive collecting program of Thompson & Hunt; however, some of the apparent increases in abundance appear to be significant, as will be shown later. Thompson & Hunt believed that their data indicated a pronounced increase in the abundance and distribution of *Semotilus atromaculatus, Ericymba buccata,* and *Micropterus dolomieui* and suggested the recent arrival in the county of *Aplodinotus grunniens.*

A number of species showed apparent decreases in abundance and distribution. Some of the apparent decreases were probably the result of cyclic changes in populations; others probably represent gradual disappearance of species. Thompson & Hunt cited *Hybognathus nuchalis* and *Minytrema melanops* specifically and noted that several other species seemed to have declined in abundance. Comparison of the distribution maps of Forbes & Richardson and those of Thompson & Hunt suggests that a reduction in numbers of stations represented, in numbers of drainages occupied, or in numbers of both, also occurred in the following species: *Dorosoma cepedianum, Carpiodes cyprinus, C. velifer,* and *Moxostoma macrolepidotum.* However, in these species the apparent decrease in abundance and distribution was probably not real, as there was no evidence of their decrease from 1928 to 1959. Moreover, all are large fishes characteristic of deep pools and can be easily missed when collecting is done principally with a 10-foot minnow seine. Another group of fishes, all of which are creek species of small size, also showed some reduction in numbers of stations or drainages occupied, or both; but their apparent reduction is assumed to have been due to only a temporary decline in their populations about 1928, as in 1959 none showed evidence of reduced occurrence. A third group of species, to be cited later, showed striking decrease in abundance and distribution between 1901 and 1928. Their continued decline is documented by more recent data.

Investigations Between 1929 and 1959

Although some observations on fishes of Champaign County were made between 1929 and 1959 by various fishermen and by personnel of the Illinois Natural History Survey and the University of Illinois, no records of unusual interest were published. Several of Thompson & Hunt's records were cited by Luce (1933), who utilized their collections from the headwaters of the Kaskaskia in his study of that river, and by O'Donnell (1935) in his list of Illinois fishes. During the next several years, material from Champaign County was cited in several revisionary studies, but none of these contributed new distributional information. Although no concerted effort was made to obtain collections from the county, occasional field work by two University of Illinois biologists, the late H. J. Van Cleave and H. H. Shoemaker, and by ecology classes at the University contributed to the knowledge of local fishes. Personnel of the Natural History Survey, with headquarters in the center of the county, have been alert to major changes in field populations and to alterations of habitats in the area; they have supplemented their own observations through contacts with fishermen and other local observers.

Recent Survey Records

Collections in 1959, and subsequently, added 10 species to the known fauna of Champaign County. Six of these (*Amia calva, Carassius auratus, Ictalurus nebulosus, Gambusia affinis, Roccus mississippiensis,* and *Lepomis microlophus*) are known to be introduced species; three (*Lepisosteus osseus, Noturus nocturnus,* and *Percina sciera*) are native and presumably were always present but were overlooked by previous investigators; one (*Notropis lutrensis*) recently extended its range eastward into Champaign County. Our collections failed to reveal the presence of 11 species that were taken 30 years before by Thompson & Hunt:

Ictiobus cyprinellus
Ictiobus niger
Hybopsis amblops
Notropis amnis
Notropis boops
Opsopoeodus emiliae
Pimephales vigilax
Noturus exilis
Lepomis punctatus
Etheostoma chlorosomum
Etheostoma gracile

Our collections also failed to include three species (*Ictiobus bubalus, Hybopsis aestivalis,* and *Notropis heterolepis*) taken

Table 6.—Summary of collections and the number of species taken and recorded in Champaign County by various collectors. Figures in parentheses indicate the numbers of collecting stations.

Occurrence Category	Pre-Forbes & Richardson (?)	Forbes & Richardson (48)	Thompson & Hunt (126)	Larimore & Smith (152)
Number of species taken	2	63	74	74
Number of previously unrecorded species taken	2	63	15	10
Number of previously recorded species retaken	0	0	59	64
Number of previously recorded species not taken	0	2	6	16
Total number of species recorded (cumulative)	2	65	80	90

in the county 60 or more years ago by Forbes & Richardson or by Large. Two species (*N. atherinoides* and *Etheostoma asprigene*) taken by Forbes & Richardson, but not by Thompson & Hunt, were rediscovered in the county in 1959. In all, our collections represented 74 species, 64 of which had been previously reported from Champaign County. The number of collecting stations, number of species represented, and other data for each survey are summarized in table 6.

Summary of Changes Over 60-Year Period

With full realization that fish populations may vary from one year to the next and that comparison of results of three widely spaced surveys could thus lead to erroneous inferences, we believe that certain changes are demonstrable in the Champaign County fish fauna over the period of study reported here. (In this paper, *occurrence* of a species is measured in relation to both the number of localities or stations represented and the number of drainages in which it was found.)

Evidence provided by the three surveys reveals numerous changes in occurrence of the fish fauna of the county. Of the 9 species added in 1959, at least 1 (*Notropis lutrensis*) appeared to have dispersed naturally from the west, and 15 species, which presumably had always been present in the county, showed increases in abundance and in number of drainages occupied. These 16 species, the percentage of stations in which they occurred, and the number of drainage systems in which they were found in each survey are listed in table 7. Increased occurrence of these 16 species is suggested by scrutiny of the distribution maps, figs. 15–70, pages 362–75.

On the basis of table 7, we could assume that the large fishes (*Pylodictis olivaris,* both species of *Moxostoma, Micropterus dolomieui,* and *Cyprinus carpio*) appeared to be more common in 1959 than formerly because the modern collecting apparatus used was more efficient than seines in sampling deep pools. Improved sampling methods could conceivably explain the slight increases in occurrence shown for *P. olivaris,* the two species of *Moxostoma,* and part of the increase in occurrence shown for *C. carpio,* which is easily shocked.

It has been suggested that the mushrooming of *Cyprinus carpio* populations within the past 30 years could be associated with the increased water pollution in the same period. Perusal of the list of species in table 7 reveals that the two other pollution-tolerant fishes, *Notropis umbratilis* and *Semotilus atromaculatus,* showed only modest increases in abundance in this period but that their great increase in abundance occurred much earlier, some time between 1899 and 1928. Moreover, gains of equal magnitude can be observed in such pollution-intolerant species as *N. rubellus* and *Hypentelium nigricans.*

Notropis rubellus, N. dorsalis, and *N. lutrensis* are of particular interest because

Table 7.—Species showing increases in frequency of occurrence (per cent of stations in which each species was taken) in Champaign County in three surveys; for each species is given the number of drainages in which it was taken in each survey.

Species	Forbes & Richardson		Thompson & Hunt		Larimore & Smith	
	Per Cent of Stations	Number of Drainages	Per Cent of Stations	Number of Drainages	Per Cent of Stations	Number of Drainages
Notropis lutrensis	0	0	0.0	0	13.8	2
Ambloplites rupestris	0	0	0.8	1	10.5	3
Moxostoma anisurum	0	0	0.8	1	4.6	2
Pylodictis olivaris	0	0	0.8	1	2.6	3
Notropis rubellus	0	0	2.4	1	3.9	1
Noturus flavus	2.1	1	4.0	3	14.5	3
Notropis dorsalis	2.1	1	4.0	1	18.4	3
Moxostoma macrolepidotum	2.1	1	4.8	2	5.3	1
Micropterus dolomieui	2.1	1	12.7	3	24.3	4
Cyprinus carpio	8.3	3	8.6	3	36.8	6
Hypentelium nigricans	14.6	3	21.4	5	27.6	5
Notropis umbratilis	16.7	2	54.8	6	63.8	6
Semotilus atromaculatus	18.7	3	80.1	6	83.0	6
Notropis chrysocephalus	18.7	2	42.9	4	52.0	5
Hybopsis biguttata	20.8	3	36.5	3	46.0	4
Campostoma anomalum	35.4	3	50.8	5	67.1	5

they are peripheral populations, *N. rubellus* reaching its southernmost point of distribution, at least in eastern Illinois, within Champaign County, and the other two reaching their easternmost limits of distribution in the county. *N. rubellus* appears to have extended its range southward into the county between 1899 and 1928 and to have replaced the allied *N. atherinoides* in both drainages where *rubellus* was found in 1959. *N. dorsalis* has been known in the county for at least 60 years; there is evidence from another source, in addition to the Champaign County data, that its range is gradually shifting eastward. A similar trend is

Table 8.—Species showing decreases in frequency of occurrence (per cent of stations in which each species was taken) in Champaign County in three surveys; for each species is given the number of drainages in which it was taken in each survey.

Species	Forbes & Richardson*		Thompson & Hunt		Larimore & Smith	
	Per Cent of Stations	Number of Drainages	Per Cent of Stations	Number of Drainages	Per Cent of Stations	Number of Drainages
Lepomis humilis	33.3	4	10.3	3	5.9	3
Minytrema melanops	31.2	4	3.2	2	0.6	1
Ictalurus melas	25.0	4	9.5	5	4.6	5
Labidesthes sicculus	12.5	2	4.0	1	2.0	1
Pomoxis nigromaculatus	14.6	3	2.4	1	1.3	1
Esox americanus	20.8	4	20.6	5	11.2	6
Chaenobryttus gulosus	6.2	1	0.8	1	0.6	1
Hybopsis amblops	12.5	2	6.4	3	0.0	0
Pimephales vigilax	12.5	1	3.2	2	0.0	0
Etheostoma chlorosomum	2.1	1	0.8	1	0.0	0
Notropis boops	2.1	1	1.6	1	0.0	0
Opsopoeodus emiliae	2.1	1	1.6	1	0.0	0
Notropis heterolepis	4.2	2	0.0	0	0.0	0
Ictiobus bubalus	2.1	1	0.0	0	0.0	0
Hybopsis aestivalis	2.1	1	0.0	0	0.0	0

*Includes *Opsopoeodus emiliae* and *Hybopsis aestivalis* recorded by Large (1903:15, 19) shown by *N. lutrensis,* which entered the county between 1928 and 1959. *Ambloplites rupestris* and *Micropterus dolomieui* show an irrefutable increase in abundance and occurrence within Champaign County, but there is no evidence that their ranges within the state have changed. These species would have been benefited by the increased stream gradient and lower maximum water temperatures that may have resulted, as suggested in the section on Changes in Stream Habitats, from drainage and dredging operations. Similarly, *Hypentelium nigricans, N. chrysocephalus, Hybopsis biguttata, Noturus flavus,* and *Campostoma anomalum* show decided, if inexplicable, increases in occurrence within the county, but their over-all ranges within the state appeared to be the same in 1959 as 60 years before.

On the basis of evidence from the three surveys, 15 species exhibited an equally striking decrease in abundance and in shrinkage of distributional pattern within the county over the 60-year period of study. These species, the percentage of stations in which they were found, and the number of drainages in which they were taken at each survey are listed in table 8.

Data for the entire period covered by the three surveys indicate that *Ictiobus bubalus, Hybopsis aestivalis,* and *Notropis heterolepis* disappeared from Champaign County before 1928. *N. heterolepis,* if Forbes & Richardson correctly identified the specimens to which they assigned this name, is of particular interest because it occurred in two different drainage systems prior to 1899 and probably disappeared with the draining of the once extensive prairie marshes. *I. bubalus* may be expected to be taken again in Champaign County, for it occurs in large streams only a few miles outside the county.

Hybopsis amblops, Pimephales vigilax, Etheostoma chlorosomum, Notropis boops, and *Opsopoeodus emiliae* may have declined in numbers by 1928; they disappeared between 1929 and 1959. The remaining seven species listed in table 8 are still present, but they are much less common than formerly. All of them except *Esox americanus* suggest that their marked decline in the county occurred between 1899 and 1928. One, *Minytrema melanops,* was described by Large (1903:12) as "abundant in the Wabash basin and in the headwaters of the Kaskaskia" and "apparently prefers the weedy prairie creeks in situations where it is abundant." *E. americanus* was evidently about equally common in 1899 and 1928 but had decreased sharply by 1959, presumably because of the destruction by dredging of its preferred habitat (pools with luxuriant aquatic vegetation).

The extirpation of six other species (*Ictiobus cyprinellus, I. niger, Notropis amnis, Noturus exilis, Lepomis punctatus,* and *Etheostoma gracile*) from Champaign County is almost certain; they have not been included in table 8 because information regarding their abundance, or even their presence, was unavailable prior to the 1928 investigation. Of the extirpated species, *E. gracile, N. exilis,* and *Hybopsis amblops* are noteworthy because they were, until 1928, peripheral populations in the county. The northernmost record in the range of *E. gracile,* the easternmost record in the range of *N. exilis,* and the westernmost record of *H. amblops,* at least in this region, were in Champaign County. Within the past 30 years, shrinkage in the ranges of these three species, respectively to the south, west, and east, has occurred. This shrinkage is evident over the state as a whole as well as within Champaign County.

Despite the impressive changes in abundance and distribution of the species discussed in the paragraphs above, it is difficult to describe the changes in the Champaign County fish fauna as radical, for roughly half of the species showed no decided trends. Examination of distribution maps, figs. 15–70, that accompany this report will reveal that the occurrence of several species was remarkably similar throughout the 60-year period of observation. Several species exhibited considerable changes in distribution but these species cannot be regarded as being any more or less common, or more or less widely distributed, in the county in 1959 than they were in 1928 or 1899. In view of the great changes in land use, in the stream courses, and in the stream habitats that occurred in the county over a 60-year period, and the catastrophic effects of the several drought years since 1930,

Table 9.—The number of species of fish taken and recorded in each of the six Champaign County drainages and the number of species restricted to each of these drainages.

Survey	Sangamon		Salt Fork		Middle Fork		Kaskaskia		Little Vermilion		Embarrass	
	Species Recorded in Drainage	Species Restricted to Drainage	Species Recorded in Drainage	Species Restricted to Drainage	Species Recorded in Drainage	Species Restricted to Drainage	Species Recorded in Drainage	Species Restricted to Drainage	Species Recorded in Drainage	Species Restricted to Drainage	Species Recorded in Drainage	Species Restricted to Drainage
Forbes & Richardson	40	5	47	9	24	3	18	2	....	....	8	0
Thompson & Hunt	50	13	41	7	36	4	14	4	14	0	25	0
Larimore & Smith	54	6	51	3	47	4	39	5	18	1	32	0
Total	67	7	64	3	55	3	51	4	20	1	36	0

it is indeed astounding that many of our species were still present in the same streams in 1959 and probably in approximately the same numbers then as 30 and 60 years previously.

Results of an analysis of distribution of species by drainage systems are summarized in table 9. It will be seen that Forbes & Richardson found the Salt Fork drainage both the richest in number of species, with 47, and the most distinctive, with 9 species occurring there exclusively. On the basis of these same criteria, they found the Sangamon to be second, the Middle Fork third, the Kaskaskia fourth, and the Embarrass fifth. They made no collections in the Little Vermilion drainage. About 30 years later, Thompson & Hunt found the Sangamon richest in species and most distinctive, with a total of 50 species, 13 of which they did not find elsewhere. Other drainages ranked as follows: Salt Fork, Middle Fork, Kaskaskia, Embarrass, and Little Vermilion. Our findings were similar to those of Thompson & Hunt, except that we found fewer species restricted to a single drainage, and no species restricted to the Embarrass drainage.

The most significant results of this analysis, aside from the richness of the fauna in each drainage, are the number of species restricted to a drainage system. More than 10 per cent of the 67 species in the Sangamon, almost 9 per cent of the 51 species in the Kaskaskia, almost 6 per cent of the 55 species in the Middle Fork, roughly 5 per cent of the 20 species in the Little Vermilion and of the 64 species in the Salt Fork occurred only in their respective drainages. None of the 36 species in the Embarrass occurred exclusively in that drainage. This lack of species distinctiveness for the Embarrass is clearly evident on the distribution maps.

We can express distributional changes by examining the drainage systems and tallying the number of changes observable when the Thompson & Hunt list of species is compared with that compiled by Forbes & Richardson and the Larimore & Smith list of species is compared with that compiled by Thompson & Hunt. A summary of these changes in presented in table 10.

Table 10 indicates that the greatest number of changes between the Forbes & Richardson and the Thompson & Hunt surveys occurred in the Middle Fork drainage; 30 species were taken in one of these surveys but not the other. The least number of changes occurred in the Embarrass; 21 species were taken in one of these surveys but not the other. No collections were made in the Little Vermilion by Forbes & Richardson. Within the approximately 30 years between the survey of Forbes & Richardson and the survey of

Table 10.—Changes (increases or decreases) between surveys (FR = Forbes & Richardson; TH = Thompson & Hunt; LS = Larimore & Smith) in the number of species of fish in Champaign County drainages. Changes include both the taking of species not previously taken and the failure to retake species previously taken in a drainage. Forbes & Richardson made no collections in the Little Vermilion.

Drainage	FR–TH	TH–LS	Total Changes
Kaskaskia	27	20	47
Middle Fork	30	15	45
Sangamon	29	15	44
Salt Fork	22	17	39
Embarrass	21	11	32
Little Vermilion	..	8	8
Total changes	129	86	215

Thompson & Hunt, a total of 129 changes in distribution occurred in the five drainage systems considered here. Between 1928 and 1959, the greatest number of changes occurred in the Kaskaskia; the least number of changes occurred in the Little Vermilion drainage. Within the period between 1928 and 1959, a total of 86 changes occurred in the six drainages of the county. For the over-all period of study, approximately 60 years, the greatest number of changes occurred in the Kaskaskia drainage.

If changes in the occurrence of fish reflect the amount of modification of a stream and its habitats, it should follow that much greater modification occurred during the first 30 years of this century than during the second 30 years. This assumption is substantiated by the historical record of land use and can be observed by noting, in table 10, the interval when the greatest changes in species composition occurred. It should also follow that the most extensive changes in land use early in this century were in the Middle Fork and Sangamon basins and, after 1928, in the Kaskaskia and Salt Fork basins. The small amount of change in the Little Vermilion is probably due to its small size and comparatively small number of habitats; only the extreme headwaters of this drainage are in Champaign County.

ECOLOGICAL ASSOCIATIONS

Ecological associations can be drawn between a species of fish and various environmental factors comprising its habitat, or between a species of fish and other species of fishes with which it is found. However, a clear separation of the influences of the physical environment from those exerted by fishes is often difficult or impossible.

Species Associated With Various Stream Habitats

The stream habitats defined in table 4 on the basis of water velocity, depth, and area of drainage basin contained fish populations characteristic of each. As shown in the tabulations below, some species taken in the Champaign County surveys were limited in their occurrence to a specific habitat, whereas others were more generally distributed. Our assignment of a particular species to a particular habitat was complicated by seasonal changes in fish distribution, differences in distribution of young and adult fish, and lack of uniformity throughout each habitat.

Species of Rivulets and Small Creeks

Etheostoma spectabile
Campostoma anomalum
Semotilus atromaculatus
Fundulus notatus
Pimephales notatus
Erimyzon oblongus, young
Catostomus commersoni, young
Lepomis cyanellus, young
Ictalurus natalis, young
Ictalurus melas, young

Species of Large Creeks

Riffles: sand and fine gravel
Ericymba buccata
Etheostoma spectabile
Notropis dorsalis
Campostoma anomalum
Phenacobius mirabilis
Riffles: gravel and rubble
Etheostoma caeruleum
Etheostoma blennioides
Etheostoma flabellare
Pools: shallow, moderate current
Notropis chrysocephalus
Hybopsis biguttata
Semotilus atromaculatus
Catostomus commersoni
Notropis stramineus
Notropis spilopterus

Pimephales notatus
Noturus miurus
Etheostoma nigrum
Cyprinus carpio, young
Moxostoma spp., young
Carpiodes spp., young
Hypentelium nigricans, young
Percina maculata
Carpiodes cyprinus
Hybognathus nuchalis
Notropis lutrensis

Pools: deep, sluggish
Lepomis megalotis
Micropterus dolomieui
Ambloplites rupestris
Esox americanus
Erimyzon oblongus
Notemigonus crysoleucas
Lepomis humilis
Pimephales promelas
Aphredoderus sayanus
Lepomis macrochirus
Ictalurus natalis
Ictalurus melas
Noturus gyrinus
Notropis umbratilis
Lepomis cyanellus
Fundulus notatus

Species of Small Rivers

Riffles: sand and gravel
Notropis whipplei
Ammocrypta pellucida
Phenacobius mirabilis
Notropis dorsalis

Riffles: boulders and rubble
Hypentelium nigricans
Etheostoma blennioides
Noturus flavus
Notropis rubellus
Etheostoma zonale

Pools: shallow, moderate velocity
Moxostoma erythrurum
Percina phoxocephala
Moxostoma macrolepidotum
Carpiodes velifer
Percina caprodes
Hybognathus nuchalis
Lepomis megalotis
Lepomis cyanellus

Pools: deep, sluggish
Micropterus punctulatus
Moxostoma anisurum
Cyprinus carpio
Dorosoma cepedianum
Micropterus salmoides
Pomoxis annularis
Pylodictis olivaris
Lepomis macrochirus
Aplodinotus grunniens
Ictalurus natalis
Ictalurus melas

Species Associated With Various Ecological Factors

From each of our quantitative samples, the number and weight of each species per 100 square yards were recorded on IBM sorting cards along with measurements or appraisals of the following 13 ecological factors of the habitats: (1) average depth, (2) average width, and (3) average water velocity; composition of the bottom materials as percentage of (4) clay, (5) silt, (6) sand, (7) silt and sand, (8) gravel, and (9) rubble; occurrence of (10) aquatic vegetation, (11) debris, and (12) bank vegetation; degree of (13) water turbidity. Each of these ecological factors was assigned numerical values to express the total actual range of field measurements (examples: depth in feet, per cent sand).

For each value of an ecological factor (for example, *over bottom materials that were 30 per cent sand*), we determined:

(1) the total number of individuals of each species associated with the value.
Example: 100 creek chubs taken over 30 per cent sand.

(2) the number of collections in which this species occurred.
Example: Creek chubs occurred in 10 collections.

(3) the total number of collections associated with the ecological value.
Example: Bottom materials composed of 30 per cent sand were found in 20 collections.

(4) the average number of fish of each species found with the value, figured by dividing (1) by (3).
Example:

$$\frac{\text{100 creek chubs over 30\% sand}}{\text{20 collections over 30\% sand}} =$$

5 chubs per collection over 30% sand

(5) the per cent of collections associated with the ecological value that contained the species, figured by dividing (2) by (3).

Example:

$$\frac{\text{10 collections of chubs}}{\text{20 collections over 30\% sand}} =$$

50 per cent of collections over this bottom contained chubs

Thus, in the examples above, five creek chubs were taken per collection over 30 per cent sand bottom material, and creek chubs were present in 50 per cent of such collections.

Ecological associations were determined for collections from each drainage system and then for the entire county.

The association figures revealed (1) ecological factors that comprised the general habitat of each species (used in assigning species to stream habitats in the preceding section); (2) inconsistencies that appeared when a species was related to a specific ecological factor in one stream system and not in another; and (3) the absence of any single factor that determined the distribution or abundance of most species.

Such ecological associations may be of definite value in defining the general habitat of a species but are quite misleading in determining its environmental requirements, for the influences of each environmental factor in a natural habitat cannot be separately evaluated. We cannot be sure just which factor or factors in a habitat have a controlling influence on a species. For example, gizzard shad showed a high degree of association with deep, quiet pools. However, they may have been responding not to depth or to low water velocity but to the soft sands and silts usually found in such pools. Too, a species might have been closely associated with a specific factor that did not comprise a noticeable part of the habitat.

A few species were closely restricted to rather specialized habitats. The restrictions, while quite obvious during field collecting, were not always shown by our calculations. Some of the most notable examples were *Ammocrypta pellucida*, which occurred only in clear water flowing over clean sand; *Esox americanus*, which reached its greatest abundance in quiet, silt-bottomed pools choked with vegetation; *Noturus flavus*, which seemed to prefer deep riffles or shallow pools with moderate current and scattered rubble and flat rocks; and *Aphredoderus sayanus*, which was invariably in mud-bottomed pools of streams with little current. However, in general, most fishes showed a remarkable plasticity in their environmental tolerance.

Species Associated With Other Species

Associations between species can be determined (1) through examining which species are mutually associated with a set of ecological factors and (2) through examining the mutual occurrence and abundance of two or more species. The degree of association between pairs of several kinds of common Champaign County fishes was determined by calculating the coefficient of correlation (r) between their numbers in 100 square yards of stream. Coefficients were determined for the collections from each drainage system, as well as for the entire county. Several definite and sometimes surprising associations were evident.

Notropis dorsalis—Ericymba buccata.—Champaign County is on the edge of the range of each of these species, *Notropis dorsalis* becoming more abundant westward and *Ericymba buccata* becoming more abundant eastward. Because of the east-west separation in distribution, these two species usually do not occur abundantly in the same drainage system. They have been considered ecological equivalents, and competition between the two has been implied. Trautman (1957:376) noted the shrinking in size of the Ohio range of *N. dorsalis* and the invasion and great increase in numbers of *E. buccata* in a territory formerly occupied by *dorsalis*. However, in our Sangamon River collections, where both species were abundant, they occurred together in a highly significant degree (P less than 0.01) of association, table 11. This situation indicates their preference for similar habitats and disputes the idea that there is strong competition between the two. *N. dorsalis*, although occurring in two other Champaign County drainages (Kaskaskia and Middle Fork), was abundant only in the Sangamon, so that further comparisons could not be made.

Table 11.—Degree of association between four species of fish in the Sangamon drainage. Correlation coefficient (r) of 0.438 is significant at the 0.02 level.

Species	*Notropis chrysocephalus*	*Notropis dorsalis*	*Ericymba buccata*
Erimyzon oblongus	0.668	0.587	0.187
Notropis chrysocephalus	.....	0.874	0.464
Notropis dorsalis	.....	.....	0.771

Table 12.—Degree of association between four species of fish in the Middle Fork drainage. Correlation coefficient (r) of 0.934 is significant at the 0.02 level.

Species	*Erimyzon oblongus*	*Notropis chrysocephalus*	*Phenacobius mirabilis*
Catostomus commersoni	0.977	0.965	0.978
Erimyzon oblongus	.....	0.958	0 935
Notropis chrysocephalus	.....	.....	0.973

Notropis chrysocephalus — Erimyzon oblongus.—These species formed one of the least expected associations observed among Champaign County fishes, occurring in a significant (P 0.02 or less) association in three of five drainage systems, fig. 12. In the Sangamon drainage they were closely associated with the two species previously discussed, table 11. In the Middle Fork drainage, however, they formed a strong association with *Phenacobius mirabilis* and *Catostomus commersoni*, table 12.

Catostomus commersoni — Phenacobius mirabilis. — These two species occurred in significant associations (P 0.02 or less) in three of the five Champaign County drainages considered, as well as in the county-wide analysis. They were significantly associated with *Erimyzon oblongus* and *Notropis chrysocephalus* in the Middle Fork drainage, table 12. Both species were closely associated with *Hybopsis biguttata* in the Salt Fork drainage, fig. 12.

Miscellaneous Associations.—Several species showed different associations in different stream systems; for example, *Notropis umbratilis* was significantly (P 0.02 or less) associated with such species as *Hypentelium nigricans, Notemigonus crysoleucas, Notropis chrysocephalus, Phenacobius mirabilis,* and *Erimyzon oblongus*, each association in a different stream. This lack of similarity or consistency in associations seems to suggest little interdependence between species but rather dependence of certain

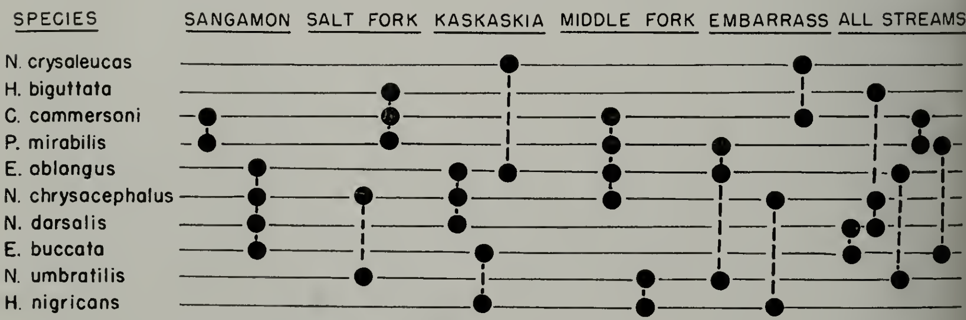

Fig. 12.—Significant associations of several fishes in five drainages of Champaign County. The coefficient of correlation (r) was better than the 0.02 level of significance except in the column "All Streams," where the associations between *Notropis dorsalis* and *Ericymba buccata* and between *N. dorsalis* and *Hybopsis biguttata* were significant only to the 0.03 level.

species on certain ecological factors. These factors may occur together in one stream system, thus bringing two species together, or they may be separated in another stream system, thus separating species. Two species might occur together temporarily or abnormally, as during periods of low water when many species may be forced into constricted water areas.

Thompson & Hunt (1930:66) stated, "Most instances of the association of different species of fishes are explained satisfactorily by similar environmental preferences." However, they pointed out a very significant exception to this statement in their discovery of a close association between *Hybopsis biguttata* and *Notropis chrysocephalus*. For these two species, they suggested a direct dependence, at least at some stage in the life cycle. Our 1959 collections revealed a significant (P less than 0.01) association between these two minnows when all the collections for the county were considered together, but no consistency of association in any of the separate drainage systems, even though both species were taken in rather great numbers in four of the systems.

GENERAL ABUNDANCE AND OCCURRENCE

The use of collecting methods in 1959 that differed from those of 1928 contributed to the difficulty of comparing the two surveys with respect to the general abundance and occurrence of fishes as recorded.

Some of the variables in such comparisons were eliminated by consistently following throughout each survey a procedure adapted to it and by excluding from consideration any stations that in either survey were influenced strongly by pollution or that were not visited by both survey parties. Seventy-one collections were then available for comparison.

Average Number of Species Per Station

A consistently larger number of species per station was found in collections taken in the 1959 than in the 1928 survey. The average was 13.2 species per station in 1928 and 19.0 in 1959; the ratio was 1:1.4, table 13. The samples taken in the later survey were considerably larger numerically and thus might be expected to contain a higher percentage of those species present at the collecting stations. In the two surveys, the drainages were in the same order with respect to average number of species per station; for example, in each survey, the Middle Fork had the largest number of species per station and the Embarrass the smallest number.

In the 1959 survey, quantitative collections from the blocked-off stations produced between 88 and 97 per cent of the total number of species collected at

Table 13.—Average number of species per station and average number of fish per 100 square yards taken in 1928 and 1959 at 71 stations (not noticeably affected by pollution) in five major drainages of Champaign County (no quantitative samples were taken from the Little Vermilion); also, average number of pounds of fish per 100 square yards in 1959.

Drainage System	Number of Stations	Average Number of Species per Station				Average Number of Fish per 100 Square Yards			Average Number of Pounds of Fish per 100 Square Yards in 1959
		1928	1959						
		Total Collection	Quantitative Sample	Total Collection	Ratio 1928:1959	1928	1959	Ratio 1928:1959	
Middle Fork	5	20.6	30.4	31.4	1:1.5	553	286	1:0.5	5.10
Sangamon	28	17.3	20.1	21.9	1:1.3	468	562	1:1.2	2.89
Salt Fork	18	9.1	14.4	15.3	1:1.7	429	470	1:1.1	2.80
Embarrass	9	6.8	12.6	14.3	1:2.1	185	571	1:3.1	1.74
Kaskaskia	11	11.2	13.7	15.5	1:1.4	202	150	1:0.7	0.90
All systems	71	13.2	17.4	19.0	1:1.4	387	457	1:1.2	2.57

any site; in other words, we added approximately 10 per cent more species by "cruising" with a seine in adjacent habitats. With the small amount of effort expended, "cruising" furnished desirable additions to the collections.

Average Number of Fish Per 100 Square Yards

Although the average numbers of fish per 100 square yards collected in both surveys varied greatly from stream to stream, table 13, the county averages for the two surveys did not differ greatly; the ratio of the 1928 to the 1959 average was 1:1.2. The most striking difference between the two surveys was that the Middle Fork produced the greatest number of fish per 100 square yards in 1928 and next to the lowest number in 1959, whereas the Embarrass yielded the lowest number in 1928 and the highest number in 1959. There was no apparent habitat change that might account for this difference. A difference of the same kind was not evident in the number of species taken or in the weight of fish collected in the two surveys of these streams. The highest ratio of increase from 1928 to 1959 in the number of species as well as in the number of fish collected per 100 square yards occurred in the Embarrass, although in the 1959 survey the number of species and the pounds collected in the stream were low, table 13.

Average Weight of Fish Per 100 Square Yards

The weights of Champaign County fish taken in 1959 could not be compared with those taken in 1928 because there were no exact weight data from the Thompson & Hunt survey. Thompson & Hunt (1930:39) estimated that they took 150 pounds of fish per acre in the 1928 collections. In the 1959 survey, the number of pounds per 100 square yards varied from 0.9 in the Kaskaskia to 5.1 in the Middle Fork and averaged 2.6 for the entire county. This county average is equivalent to 124.4 pounds per acre.

The poundage figures from the 1959 survey should not be regarded as representing the total population present in any of the areas fished. Using the electrofishing equipment employed in the 1959 survey of Champaign County to fish Jordan Creek, a small stream in adjoining Vermilion County, Larimore (1961:3–5) took an average of 54 per cent of the weight and 51 per cent of the number of the fish population present in the areas fished. The Jordan Creek population taken by electrofishing and other means amounted to nearly 25,000 fish weighing 163.9 pounds per acre. If the same rate of electrofishing success applied to our Champaign County collections, the total populations would have been close to an average of 250 pounds per acre for the stations worked in 1959.

DISTRIBUTION AND STREAM SIZE

Thompson & Hunt, using their 1928 Champaign County collections, explored both the composition and the size of fish populations in relation to stream size, expressed as square miles of drainage basin at point of collection. They related stream sizes to the numbers and weights of fish, to the average sizes of fish taken, to the number of species, and to the distribution of various species. They grouped their collections into 10 classes according to stream size at the collecting stations, beginning with stations having 0.5–1.0 square mile of drainage and doubling the stream sizes up to the class of 256.0–512.0 square miles.

Relationships With Stream Size

We have analyzed quantitative data from the 1959 survey in a manner similar to that used by Thompson & Hunt in order to determine whether the 1959 collections support the conclusions of Thompson & Hunt (1930:41–6), given in italics following paragraph headings below. Including only those stations receiving no noticeable pollution and those visited in both 1928 and 1959, table 14, we plotted our data for 1959 in fig. 13 to correspond roughly to the treatment shown by Thompson & Hunt in their fig. 6; that is, we combined the data for our two smallest classes of stream size and for our three largest classes of stream size. Thompson & Hunt combined the data for their three smallest and their three largest classes of stream sizes. We made no quantitative collections from the two smallest

Table 14.—Average number of species per station and average number and weight of fish taken per 100 square yards in 1928 and 1959 at 71 stations (not noticeably affected by pollution) classified by size of drainage basin; also, average number of pounds of fish per 100 square yards in 1959.

Stream Size (Square Miles of Drainage)*	Number of Stations	Average Number of Species per Station				Average Number of Fish per 100 Square Yards			Average Number of Pounds of Fish per 100 Square Yards in 1959
		1928 Total Collection	1959 Quantitative Sample	1959 Total Collection	Ratio 1928: 1959	1928	1959	Ratio 1928: 1959	
2–4	2	3.0	7.5	8.5	1: 2.8	126	1700	1:13.4	2.9
4–8	4	10.2	10.5	11.5	1: 1.1	676	617	1:0.9	2.8
8–16	13	9.5	12.2	13.5	1: 1.4	462	718	1:1.6	2.2
16–32	10	13.3	15.6	16.2	1: 1.2	539	704	1:1.3	2.1
32–64	17	14.2	15.9	17.9	1: 1.3	397	367	1:0.9	2.7
64–128	5	14.0	21.0	21.8	1: 1 6	345	440	1:1.3	3.7
128–256	10	20.0	26.1	28.3	1: 1.4	309	97	1: 0.3	3.7
256–512	10	11.9	22.8	24.9	1: 2.1	157	80	1: 0.5	1.5

*Classification used by Thompson & Hunt (1930). In our work, we considered the numerals as designating size limits, so that a stream classified as size 4–8 had a drainage area of more than 4 and not more than 8 square miles.

units of stream size treated by Thompson & Hunt; hence, our first point represents stations having 2–8 square miles of drainage, not 0.5–4 miles as in the treatment by Thompson & Hunt.

Number of Species and Stream Size.—*The number of species of fishes per collection increases downstream.* This hypothesis of Thompson & Hunt was supported by our collections in 1959. Our

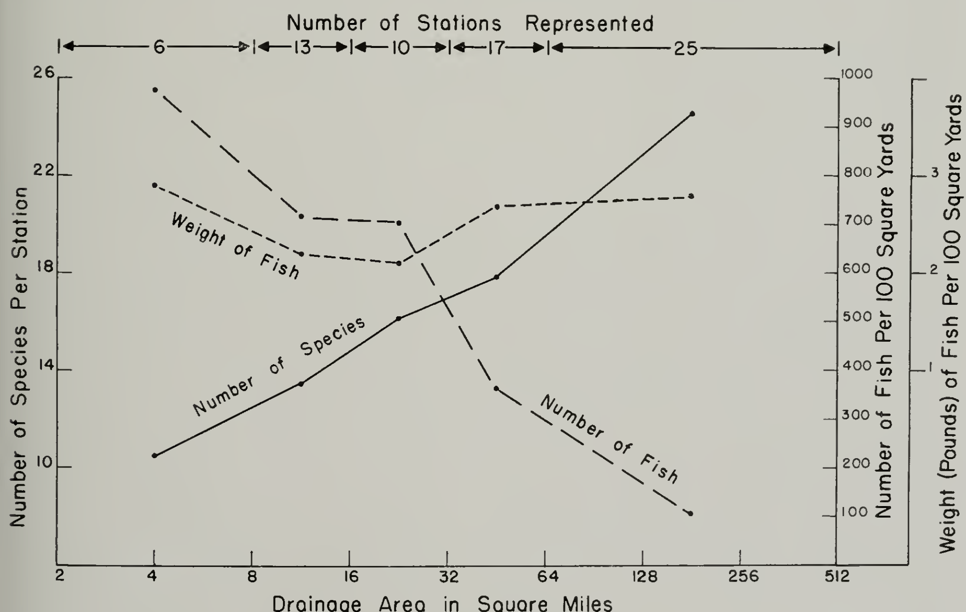

Fig. 13.—Relationships of weight, number of individuals, and number of species to size of the drainage area. Data for collections from the two smallest and the three largest areas of stream size, table 14, were combined, as explained in the text under Relationships With Stream Size on page 340.

Table 15.—Correlation between size of drainage area (square miles) and the number of species per collection and the number and weight of fish taken per 100 square yards at 70* stations in 1959.

Drainage System	Number of Collections	Coefficient of Correlation (r) with Square Miles of Drainage		
		Number of Species per Collection	Number of Fish per 100 Square Yards	Pounds of Fish per 100 Square Yards
Middle Fork	5	0.76	–0.94	0.19
Sangamon	28	0.66	–0.34	–0.18
Salt Fork	17	0.73	–0.62	–0.16
Embarrass	9	0.64	- 0.46	–0.36
Kaskaskia	11	0.58	0.18	0.11
All systems	70	0.64	–0.30	0.00

*One station, of the 71 used in related analyses, was omitted from the calculations in this table.

collections from all of the drainage systems in the county showed an increase in the number of species in a downstream direction. When all of our collections for the county were combined, table 14 and fig. 13, we found a significant positive relationship (r = 0.64, table 15) between number of species and downstream direction. The average numbers of species taken in the areas farthest downstream in both 1928 and 1959 were slightly below the projected average numbers, possibly because the sampling methods were not so well adapted to the largest water areas as to the smaller areas upstream.

An increase in the number of species in a downstream direction probably resulted from the greater variety of habitats associated with increasing stream size: many stations in large streams included units of small stream habitats. Thompson & Hunt pointed out that only unspecialized species can live under the widely varying conditions of the small streams.

Number of Fish and Stream Size. —*The actual number of fishes per unit area decreases downstream.* Most of our collections supported this hypothesis of Thompson & Hunt. Among our collections, only those from the Kaskaskia showed no definite inverse relationship between numbers of fish and stream size, table 15. Our collections from all of the streams in the county averaged together revealed a definite decrease in the number of individuals per unit area downstream, fig. 13 and table 15.

Fish Weight and Stream Size.—*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.* The average size of the fish we collected fluctuated greatly from station to station, even in streams of similar size; however, the average size of individual fish increased generally in the downstream direction. The downstream increase in average size of individuals was influenced by the occurrence of a greater number of large adults of large species (the suckers, catfishes, basses) than was found upstream.

In our collections, the weight of fish flesh per unit area, as well as the average size of fish, fluctuated greatly from station to station, even in streams of similar size. The correlation between fish weight and stream size was low in each stream and for the county as a whole, table 15. However, the average numbers of pounds of fish per 100 square yards were similar enough in streams of different sizes, table 14, that when plotted, fig. 13, they lend some support to the idea that total weight of fish flesh per unit area is similar in streams of different sizes.

Frequency Distribution and Stream Size.—*Fishes . . . exhibit frequencies which vary with stream size in a very consistent and definite manner for each species.* The frequency distribution of our fishes in relation to stream size is shown in tables 16–23. Distribution patterns were different for each species; some species showed definite patterns of distribution based on stream sizes, whereas others occurred seemingly with no relation to stream sizes.

As might be expected in a group of streams that differed from each other in

Table 16.—Suckers. Average numbers of each of several species taken in the 1959 survey (quantitative samples only) in streams of various size ranges. Each species average is for only those stream systems in which the species occurred in the quantitative collections.

SPECIES	DRAINAGE AREA OF STREAM IN SQUARE MILES AT POINT OF COLLECTION							
	2——4	4——8	8——16	16——32	32——64	64——128	128——256	256——512
Erimyzon oblongus	105.6	4.6	12.6	2.9	5.2	5.3	0.3	0.3
Catostomus commersoni	6.2	8.0	2.9	1.7	2.9	3.4	1.7	0.8
Hypentelium nigricans	----	0.2	0.1	1.2	1.0	1.9	1.5	0.6
*Moxostoma macrolepidotum**	----	----	----	----	----	----	0.2	0.2
Moxostoma anisurum†	----	----	----	----	tr.	----	----	tr.
Moxostoma erythrurum‡	----	----	----	0.2	tr.	----	2.4	1.6
Carpiodes cyprinus‡	----	----	----	0.1	1.4	11.2	0.4	0.1
Carpiodes velifer§	----	----	----	----	----	----	1.0	tr.

*Sangamon only.
†Sangamon and Salt Fork only.
‡Sangamon, Salt Fork, and Middle Fork only.
§Middle Fork only.

Table 17.—Mud-eating minnows. Average numbers of each of several species taken in the 1959 survey (quantitative samples only) in streams of various size ranges. Each species average is for only those stream systems in which the species occurred in the quantitative collections.

SPECIES	DRAINAGE AREA OF STREAM IN SQUARE MILES AT POINT OF COLLECTION							
	2——4	4——8	8——16	16——32	32——64	64——128	128——256	256——512
Pimephales notatus	445.9	126.6	91.6	168.4	68.7	55.1	15.2	10.1
Campostoma anomalum	566.7	109.6	99.2	66.0	25.5	38.7	7.9	5.2
*Pimephales promelas**	----	----	11.3	2.0	0.6	0.2	tr.	0.1
Hybognathus nuchalis†	----	----	0.2	----	0.1	33.6	----	----

*Kaskaskia and Sangamon only.
†Kaskaskia only.

Table 18.—Minnows of the genus *Notropis*. Average numbers of each of several species taken in the 1959 survey (quantitative samples only) in streams of various size ranges. Each species average is for only those stream systems in which the species occurred in the quantitative collections.

SPECIES	DRAINAGE AREA OF STREAM IN SQUARE MILES AT POINT OF COLLECTION							
	2——4	4——8	8——16	16——32	32——64	64——128	128——256	256——512
Notropis spilopterus	----	0.2	0.2	0.6	0.5	4.1	5.0	13.4
Notropis stramineus		0.2	32.3	12.5	16.9	33.2	5.1	9.5
Notropis umbratilis	57.8	0.2	1.6	2.2	4.7	1.5	1.8	2.4
Notropis chrysocephalus	----	15.2	78.0	158.7	53.2	18.1	6.1	12.1
*Notropis dorsalis**	----	----	109 0	112.1	36.2	7.1	0.6	1.5
Notropis lutrensis†	----	----	14.9	0.4	1.0	4.6	----	--
Notropis whipplei‡	----	----	0.1	0.4	----	0.5	0.6	1.6
Notropis rubellus§	----	----		----	----	----	1.4	----

*Sangamon, Middle Fork, and Kaskaskia only.
†Kaskaskia and Sangamon only.
‡Sangamon, Embarrass, and Middle Fork only.
§Middle Fork only.

habitat succession and in degree of human-induced modification, most fish species showing definite patterns of distribution based on stream size did not exhibit these patterns in all the Champaign County streams in which they were present. However, some support for the Thompson & Hunt concept expressed above was found. The following species showed somewhat consistent distribution patterns

Table 19.—Other minnows and the carp. Average numbers of each of several species taken in the 1959 survey (quantitative samples only) in streams of various size ranges. Each species average is for only those stream systems in which the species occurred in the quantitative collections.

Species	Drainage Area of Stream in Square Miles at Point of Collection							
	2–4	4–8	8–16	16–32	32–64	64–128	128–256	256–512
Semotilus atromaculatus	250.0	263.8	130.9	55.2	56.1	31.3	4.3	8.1
Phenacobius mirabilis	0.6	1.1	5.2	1.3	1.0	1.5	0.4	0.1
Ericymba buccata	----	11.1	67.2	8.9	38.0	29.3	1.5	0.4
*Hybopsis biguttata**	20.8	0.5	52.0	23.3	6.5	9.0	0.7	1.4
Notemigonus crysoleucas	----	----	0.2	tr.	0.3	0.8	1.3	0.5
Cyprinus carpio	----	----	3.5	0.2	4.3	3.8	1.0	0.3

*All streams except Embarrass.

Table 20.—Catfishes. Average numbers of each of several species taken in the 1959 survey (quantitative samples only) in streams of various size ranges. Each species average is for only those stream systems in which the species occurred in the quantitative collections.

Species	Drainage Area of Stream in Square Miles at Point of Collection							
	2–4	4–8	8–16	16–32	32–64	64–128	128–256	256–512
Ictalurus natalis	4.3	----	0.4	0.9	0.5	0.2	0.1	0.1
*Noturus gyrinus**	----	----	0.1	0.3	tr.	0.2	tr.	0.1
Noturus flavus†	----	----	----	0.1	0.1	0.1	0.6	0.2
Noturus miurus‡	----	----	----	----	0.1	----	1.2	----
Ictalurus punctatus†	----	----	----	----	----	----	0.3	0.3
Pylodictus olivaris§	----	----	----	----	----	----	0.1	----

*Salt Fork, Sangamon, and Kaskaskia only.
†Salt Fork, Middle Fork, and Sangamon only.
‡Middle Fork and Embarrass only.
§Middle Fork only.

Table 21.—Sunfish and bass. Average numbers of each of several species taken in the 1959 survey (quantitative samples only) in streams of various size ranges. Each species average is for only those stream systems in which the species occurred in the quantitative collections.

Species	Drainage Area of Stream in Square Miles at Point of Collection							
	2–4	4–8	8–16	16–32	32–64	64–128	128–256	256–512
Lepomis megalotis	----	1.5	0.3	0.2	0.7	0.6	0.8	0.2
*Micropterus dolomieui**	----	3.2	0.8	1.2	1.3	0.3	1.3	0.2
Micropterus punctulatus†	----	8.2	----	----	----	----	7.0	----
Lepomis macrochirus‡		----	tr.	0.1	----	0.2	0.1	tr.
Lepomis cyanellus	5.0	----	0.2	0.6	1.2	2.8	2.0	1.3
*Ambloplites rupestris**	----	----	----	0.4	----	----	0.6	0.3
Micropterus salmoides§	----	----	----	----	----	----	0.1	0.2
*Pomoxis annularis**	----	----	----	----	----	----	0.1	tr.
Lepomis humilis†	----	----	----	----	----	----	0.9	----

*Salt Fork, Middle Fork, and Sangamon only.
†Middle Fork only.
‡Salt Fork, Kaskaskia, and Sangamon only.
§Salt Fork and Sangamon only.

in relation to stream size in at least three of five drainage systems in the county:

Catostomus commersoni
Erimyzon oblongus
Hypentelium nigricans
Cyprinus carpio
Ericymba buccata
Ictalurus natalis
Lepomis cyanellus
Etheostoma spectabile

Because of great variation in habitat succession among Champaign County streams, we might suppose that the species showing some consistency in distribution pattern in relation to stream size were those adapted to a wide variety of habitat conditions or to a set of conditions closely related to stream size. The following species apparently were not adapted to these conditions, for their distribution patterns showed no consistency from stream to stream and little correlation with stream or drainage size:

Notropis chrysocephalus
Notropis stramineus
Notropis umbratilis
Noturus gyrinus
Lepomis megalotis
Etheostoma blennioides
Etheostoma nigrum
Percina maculata

Thompson & Hunt suggested that the place of greatest abundance of a species might be related to a specific stream size. In 1959, each species listed below was taken in greatest abundance in a specific stream size in each drainage:

Moxostoma erythrurum
Campostoma anomalum
Hybopsis biguttata
Notropis spilopterus
Semotilus atromaculatus

Table 22.—Darters. Average numbers of each of several species taken in the 1959 survey (quantitative samples only) in streams of various size ranges. Each species average is for only those stream systems in which the species occurred in the quantitative collections.

Species	Drainage Area of Stream in Square Miles at Point of Collection							
	2—4	4—8	8—16	16—32	32—64	64—128	128—256	256—512
Etheostoma nigrum	1.2	23.7	3.9	26.9	6.5	10.4	3.9	2.5
Etheostoma spectabile	38.0	6.3	9.3	44.9	8.9	0.2	0.4	0.2
Percina maculata	...	4.1	0.1	0.5	0.7	0.4	0.8	0.4
*Etheostoma flabellare**	...	3.6	0.5	3.6	0.5	...	tr.	0.1
Etheostoma caeruleum†	...	0.4	0.4	...	0.2	...	0.1	...
Etheostoma blennioides‡	...	0.8	...	...	0.2	0.1	0.9	0.1
Percina caprodes§	...	...	...	0.1	0.1	...	...	0.1
Percina phoxocephala¶	...	...	...	...	tr.	...	0.7	0.3
Etheostoma zonale‖	...	...	...	...	...	...	tr.	0.2

*Salt Fork, Middle Fork, and Sangamon only.
†All streams except Sangamon.
‡Salt Fork, Middle Fork, and Embarrass only.
§Kaskaskia, Sangamon, and Embarrass only.
¶Sangamon and Middle Fork only.
‖Sangamon only.

Table 23.—Miscellaneous fishes. Average numbers of each of several species taken in the 1959 survey (quantitative samples only) in streams of various size ranges. Each species average is for only those stream systems in which the species occurred in the quantitative collections.

Species	Drainage Area of Stream in Square Miles at Point of Collection							
	2—4	4—8	8—16	16—32	32—64	64—128	128—256	256—512
*Fundulus notatus**	...	...	21.4	4.9	0.9	0.8	0.1	0.1
Aphredoderus sayanus†	...	...	0.5	tr.	tr.	0.2	...	tr.
Esox americanus‡	...	...	0.2	...	0.2	0.5	0.2	...
Dorosoma cepedianum§	...	...	...	...	0.3	...	0.3	2.0
Labidesthes sicculus¶	...	...	...	...	...	...	...	tr.

*All streams except Middle Fork.
†Sangamon, Embarrass, and Kaskaskia only.
‡Embarrass, Kaskaskia, and Middle Fork only.
§Sangamon only.
¶Salt Fork only.

Other hypotheses by Thompson & Hunt suggest that in certain species the entire population is confined to a certain stream size of very narrow limits. In the 1959 collections, none of the species (among those taken in sufficient numbers to support such a conclusion) was confined to a certain stream size in more than two or three of the five county drainages considered here. This lack of restricted distribution was due probably to the lack of restricted habitats; in streams of the sizes found in Champaign County, some habitats that are characteristic of large streams were found upstream and many habitats that are characteristic of small streams were found downstream. Even ecological factors most closely related to stream size, such as bottom materials and vegetation, were not restricted to a degree that was known to limit the distribution of any species.

In both 1928 and 1959, young and adults of most species occurred abundantly in the same areas. However, the young of some of the suckers had their greatest frequency of occurrence upstream. The following species (in addition to most of the suckers, with their well-known upstream movements to spawn in spring) showed proportionately greater numbers of small fish than large in the upstream areas:

Campostoma anomalum
Cyprinus carpio
Hybognathus nuchalis
Ictalurus natalis
Ambloplites rupestris
Lepomis macrochirus
Micropterus dolomieui
Micropterus punctulatus

Conclusions on Relationships

Information from the 1959 collections reinforced the hypotheses of Thompson & Hunt regarding the distribution of number of species and number of individuals per unit area in relation to stream size, and it agreed moderately well with their theories regarding average size of fish and distribution of weight per unit area. Some of the other suggested relationships between the fishes and stream size appear less tenable, probably because of the great variation in habitat currently found in Champaign County streams. These relationships generally follow the ecological succession of streams as illustrated by Shelford (1911) in his collections of fishes from creeks in the Chicago region. Shelford's work and the studies of Champaign County fishes are based on the assumption that similar fish communities occupy similar physiographic stages in aging (base leveling) of a stream. Thompson & Hunt contributed several clear, practical expressions and interpretations of stream succession, and their use of drainage area as an expression of stream size can be considered a substantial contribution. The 1959 survey adds further to the knowledge of succession in warm-water streams. It provides data to substantiate many parts of the concept of succession, but at the same time offers an explanation for the many examples of failure of fish distribution to fit the theoretical sequence of stream succession. The major reason for this failure is that base leveling does not often produce a perfect geologic succession and a uniform progression of ecological factors.

DISTRIBUTION AND POLLUTION

Types of pollution have changed considerably during the years spanned by the three surveys of Champaign County fishes. Organic pollution, which began even before the period of the backyard privy, has existed to the present time with its modern scientific treatment of domestic wastes. Sources of chemical pollution have appeared; some of these have disappeared while others continue to threaten aquatic life. Pollution becomes most severe in areas of dense population and industrial development; thus, in Champaign County, it is most severe in the region of Champaign-Urbana, which serves as the focus of the present study. (The State of Illinois Sanitary Water Board in 1951 defined pollution to include alteration of the physical, chemical, and biological properties of any waters to render them harmful to fish or other aquatic organisms. This definition, which would include the effects of temperature change, sediments, and abnormal chemical levels in effluents, will be followed here.)

At the time Forbes & Richardson made their collections in the West Branch, around 1899, untreated organic wastes from Champaign and Urbana were carried by two gravity-flow sewers that discharged directly into the lower Boneyard creek and into the nearby West Branch proper. There was some additional pollution from stables, the power plant, and a few small industries, but the collections of Forbes & Richardson indicate that the fish population in the West Branch had not been seriously affected, as a variety of species, similar to that which might be found in nearby streams unaffected by pollution, was present, table 24.

A vivid description of conditions in the Boneyard and the West Branch of the Salt Fork for about two decades following the work of Forbes & Richardson was given by Baker (1922:170–85). By 1918, the Boneyard was apparently barren of clean-water organisms. The West Branch from Urbana to St. Joseph was laden with masses of decomposing matter made up of foul-water algae and protozoa, and its bottom was inhabited by slime worms. Even below the junction of the West Branch and the East Branch, conditions were septic, and clean-water life did not appear for a distance of several miles downstream.

In 1917, legislation permitted the organization of the Urbana-Champaign Sanitary District with the result that, by 1924, the sewage from both cities passed through a disposal plant. Although the disposal plant served to improve conditions in the West Branch, a high level of pol-

Table 24.—Numbers of collections in which each of 22 species was taken in three sections of the West Branch and below by Forbes & Richardson (FR), Thompson & Hunt (TH), and Larimore & Smith (LS). No species not taken by Larimore & Smith is included. Figures in parentheses below FR, TH, and LS indicate numbers of collections made, except that they do not include collections made by Thompson & Hunt or Larimore & Smith subsequent to their initial visits. Species taken in the subsequent visits and at no other time are indicated by +.

SPECIES	IN THE 4 MILES ABOVE SEWAGE DISPOSAL PLANT			IN THE 9 MILES BELOW SEWAGE DISPOSAL PLANT			IN THE 4 MILES BELOW JUNCTION OF WEST AND EAST BRANCHES		
	FR (3)	TH (4)	LS (4)	FR (4)	TH (4)	LS (4)	FR (3)	TH (2)	LS (2)
Creek chub	0	4	4	1	2	2	3	2	2
Green sunfish	2	4	3	4	+	1	0	0	2
Carp	0	0	3	0	0	1	0	0	2
Golden shiner	2	4	2	3	2	+	1	2	2
Bluntnose minnow	3	3	3	3	2	+	2	2	2
Redfin shiner	0	3	3	0	3	+	0	1	1
Common shiner	0	0	3	2	0	+	0	0	2
Sand shiner*	0	0	2	4	0	+	0	1	0
White sucker	1	2	2	2	0	+	1	1	1
Stoneroller	1	3	3	2	0	+	0	1	0
Silverjaw minnow	2	3	2	1	1	+	0	2	0
Creek chubsucker	3	2	3	3	0	0	0	1	1
Spotfin shiner*	3	0	+	3	1	+	0	1	2
Yellow bullhead	1	1	1	0	0	0	0	0	1
Johnny darter	1	3	2	3	0	0	3	1	0
Longear sunfish	2	2	1	4	0	+	1	1	0
Grass pickerel	1	2	0	2	0	0	1	0	1
Golden redhorse	1	0	0	2	0	0	0	0	1
Quillback	0	0	0	1	0	0	0	0	1
Bluegill	1	1	0	0	0	+	0	0	0
Black crappie	1	0	0	1	0	+	1	0	0
Hornyhead chub	0	0	+	1	0	0	0	0	0
Number of species taken in first collections	23	20	15	33	6	3	20	19	14
Number of species taken in subsequent collections	----	----	2	----	1	12	----	----	----

*Presumed to represent only this species at these stations, although name used in early surveys was known to be a composite of two or more species.

lution still existed, and very few fishes were found there by Thompson & Hunt when they made their collections in 1928. Improvements in the efficiency of the sanitary system were made at frequent intervals between 1928 and 1959, and at present most of the Champaign and Urbana wastes are given complete treatment. In recent years, Rantoul, Gibson City, and the Chanute Air Force Base have installed sewage treatment plants.

Although, in the past 60 years, Champaign County has lost such sources of pollutants as the early gas plants and stables, and has improved the sewer systems and the treatment of human waste, it still has to contend with domestic sewage from outlets illegally connected to storm sewers; chemicals that pass unchanged through the treatment plant; oils that wash from roads and machinery; wastes from canning plants, milk plants, and soybean mills; modified water temperatures; and agricultural chemicals, such as modern herbicides and insecticides. It has the University of Illinois chemical laboratories, the Chanute Air Force Base machinery, and an ever-increasing number of industries.

Along with these pollutants, there is the growing problem of an increasing volume of effluents, which may be detrimental to aquatic life, no matter how well they have been treated. The Champaign-Urbana community and the West Branch provide a good example. In October, 1917, a total flow of 3,000,000 gallons per day was reported for the Salt Fork below the disposal plant (Baker 1922:171). About half of this volume (1,500,000 gallons per day) was from the sanitary treatment plant. The natural stream flow was low when the measurement was made and is comparable to that during the low water period of September, 1959, when we studied the West Branch.

In September, 1959, the total volume of sewage going through the plant was 7,276,000 gallons per day, nearly five times the volume cited by Baker for 1917. (This and similar 1959 figures are from a monthly report of the Urbana-Champaign Sanitary District.) If the natural volume of the flow in the West Branch has not changed over these years, and the sewage effluent has increased nearly five-fold, the West Branch below the disposal plant must be nearly three times as large as it was in 1917. The total flow has changed from one-half effluent in 1917 to four-fifths effluent in 1959. In September, 1959, this effluent had a biochemical oxygen demand of 9 p.p.m., which would quickly reduce the oxygen in the natural stream water with which it was mixed; natural agitation of the flowing waters would, of course, partially replace the dissolved oxygen used up by the effluent material. In spite of the present high level of efficiency for the treatment plant, which produces an effluent that is as nearly perfect as sanitary engineers consider practical, the stream remains unfit for most aquatic life. The problem centers on the great volume of effluent that is produced and on the accumulation of chemical agents that preclude existence of clean-water organisms.

Areas of Chronic Pollution

Seven principal areas of chronic pollution, fig. 14, affect the distribution of Champaign County fishes, figs. 15–70.

The Boneyard.—Because of its location in the center of Champaign-Urbana, fig. 14, the Boneyard receives quantities of varied pollutants. Although Forbes & Richardson collected Johnny darters from the stream, some pollution probably existed then. According to Baker (1922:172), at the time of his study the Boneyard was receiving domestic pollutants as well as oil and tar from the gas works; pollution was extremely severe in 1915. Thompson & Hunt stated that the Boneyard contained no permanent fish population in 1928, although at that time, as well as in 1959, some fishes occasionally moved into polluted areas during high water and remained for short periods.

In 1958, black bullheads taken from the Market Street gutters during a period of high water were collected by several people and identified by Dr. Marcus S. Goldman. Apparently the fish had moved up the Boneyard, through the storm sewers, and out through the street drains. Except for similar brief ingressions, no fish occur at the present time in the Boneyard. It remains badly polluted by waste from improperly connected household drains and from businesses discharging directly into the ditch or into storm drains.

West Branch. — Although Forbes & Richardson found a variety of fishes in the West Branch of the Salt Fork during their survey, this creek has subsequently undergone drastic reduction in both variety of species and abundance of individuals. The West Branch is divisible into three sections: Section 1, the 4 miles of creek above the Urbana-Champaign disposal plant; Section 2, the creek from

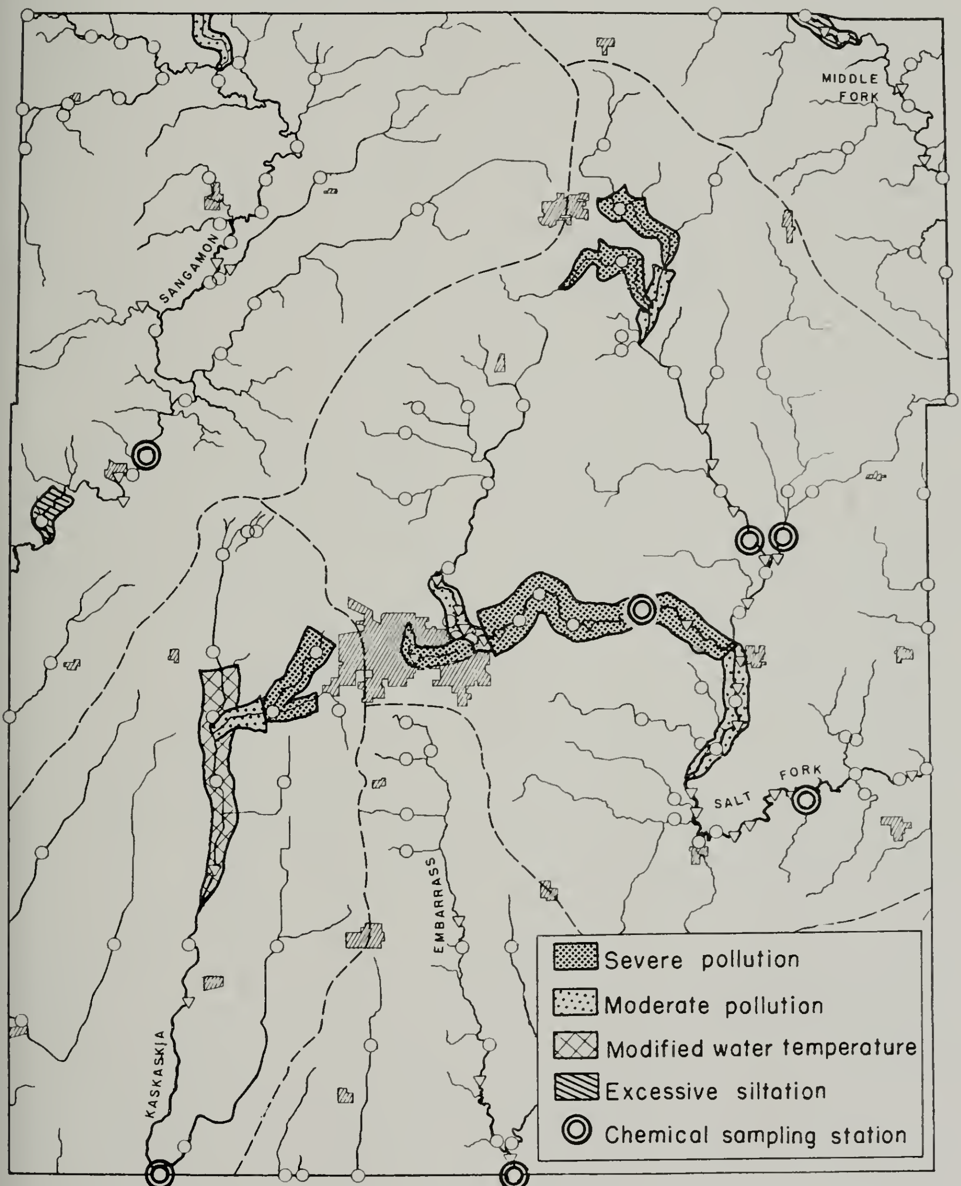

Fig. 14.—Distribution of pollution in Champaign County and location of seven stations at which chemical analyses were made in 1960. Severe pollution was found in Copper Slough and Phinney Branch west of Champaign-Urbana (city near center of map), the Boneyard in Champaign-Urbana; the West Branch of the Salt Fork east of Champaign-Urbana, the East Branch of the Salt Fork east of Rantoul (upper center of map), and the small stream from Chanute Field south of Rantoul.

the disposal plant to its junction with the East Branch; and Section 3, the stream (actually the Salt Fork) from the junction of the East and West branches downstream for a distance of 4 miles.

Section 1 presumably was relatively free of pollution when Forbes & Richardson collected at least 23 species there. In 1928, Thompson & Hunt described this section as clean and relatively free of pollution; they reported 20 species in the area. Since 1928, however, waste water from the northward expansion of Urbana and from several industrial plants has polluted this portion of the stream. In 1959, only 15 species of fish were found there, table 24.

Examples of species that disappeared early from this section were the spotted sucker, golden redhorse, suckermouth minnow, black bullhead, black crappie, and two species of darters. Species that disappeared in recent years (as pollution increased) were the grass pickerel, tadpole madtom, brook silverside, and bluegill. The most notable examples of species appearing in the section for the first time after 1900 were the carp, common shiner,

Table 25.—Number of fish per 100 square yards and number of species taken at sampling stations above and below sewage disposal plant on the West Branch of the Salt Fork by Thompson & Hunt and by Larimore & Smith. Presence of a species in very small numbers is indicated by +.

Station in Relation to Disposal Plant	Thompson & Hunt		Larimore & Smith	
	Number of Fish per 100 Square Yards	Number of Species	Number of Fish per 100 Square Yards	Number of Species
7 miles above	150	10	510	6
4 miles above	167	10	230	13
1 mile above	67	11	675	10
½ mile above	332	11	37	9
1¼ miles below	2	2	0	0
2¼ miles below	14	3	+	1
4 miles below	7	2	1	2
6¼ miles below	30	4	+	1
12 miles below	397	15	9	12

Table 26.—Number and weight (pounds) of fish per 100 square yards, and average number of species per station, collected in 1959 at various stations in two streams, one polluted (part of West Branch and Salt Fork) and one unpolluted (part of East Branch and Salt Fork). Each station is located with reference to stream size.

Stream Size (Square Miles of Drainage)*	Polluted Area				Unpolluted Area			
	Number of Stations	Number of Species per Station	Collection per 100 Square Yards		Number of Stations	Number of Species per Station	Collection per 100 Square Yards	
			Number of Fish	Weight of Fish			Number of Fish	Weight of Fish
4–8	----	----	----	----	1	7	954	1.3
8–16	----	----	----	----	3	13	809	2.8
16–32	----	----	----	----	1	15	308	1.6
32–64	2	10	356	0.7	1	14	1,338	9.1
64–128	4	1	tr.	tr.	2	20	721	7.7
128–256	1	12	9	3.0	1	15	33	3.9

*Classification used by Thompson & Hunt (1930). In our work, we considered the numerals as designating size limits, so that a stream classified as size 4–8 had a drainage area of more than 4 and not more than 8 square miles.

Table 27.—Number of species of fish collected at several stations above and below the sewage disposal plant on the West Branch of the Salt Fork. The two pools immediately above and below the mouth of the Boneyard were one-half mile above the disposal plant.

Date	Pool Above Mouth of Boneyard	Pool Below Mouth of Boneyard	1¼ Miles Below Sewage Disposal Plant	2¼ Miles Below Sewage Disposal Plant	4 Miles Below Sewage Disposal Plant	6¼ Miles Below Sewage Disposal Plant
1959						
September	9	4	0	1	2	1
1960						
March	0	1	0	0	0	0
April	1	1	0	4	1	1
May	6*	6*	0	1	8	---†
June	1*	6*	0	0	7	6
July	5	7	2	0	6	9

*Heavy oil film on banks and part of water surface. †Water level too high to permit collecting.

hornyhead chub, creek chub, and redfin shiner.

Three quantitative samples from Section 1, taken at points 4 miles, 1 mile, and one-half mile above the sewage treatment plant, table 25, indicate that several species have been able to tolerate the amount of pollution present during the past 30 years, but in 1959 the weight of fish per 100 square yards of water varied from 0.4 to 1.1 pounds, a capacity considerably below that of streams of this class (32–64 square miles of drainage) for the rest of the county, table 14.

Section 2, below the disposal plant, was already polluted at the time of the first survey. Pollution apparently had not greatly reduced the number of species present, inasmuch as Forbes & Richardson reported 33 species in the area. Soon after, however, water conditions became intolerable to most fishes (Baker 1922:117). When Thompson & Hunt collected in this 9-mile stretch, they found seven species, most of which were tolerant of moderate pollution. Only a few individuals of each species were taken, and most of these were found near outlets of drain tiles that supplied clean water. On the initial visit of the 1959 survey, the four stations that had been sampled by Thompson & Hunt produced only three species, table 24, and a total of 10 individuals. However, numerous revisits to these stations during the following spring and early summer enabled us to collect a few individuals of 12 other species.

The list of species disappearing from Section 2 is much longer than the list of species extirpated from Section 1. Species appearing for the first time in Section 2 after the advent of pollution include the carp and redfin shiner.

The drastic reduction in the number of species, in total fish weight, and in number of individuals for Section 2 in 1959 may be seen if figures in table 26 (polluted area) are compared with county-wide averages for streams having similar drainage areas (64–128 square miles), table 14. Drastic reduction in the fish population was observed in the stream just below the disposal plant, tables 25 and 27.

Section 3 (actually the Salt Fork), a 4-mile stretch directly below the confluence of the East and West branches, receives the benefit of dilution from the cleaner East Branch. Twenty species of fish were collected in this section during the first survey, 19 in the second, and 14 in the third. The average number of fish per 100 square yards taken in the third survey was very low for streams of this size, 128–256 square miles of drainage area, table 26, but the poundage (3 pounds per 100 square yards) was about average for the county. However, the quantitative data were based on a single sample that contained 14 large carp. Species other than carp were present in very low numbers, only nine fish per 100 square yards. Signs of pollution were apparent in this section, especially at times of low water.

East Branch.—The East Branch of the Salt Fork is polluted by the city of Rantoul and by Chanute Air Force Base. At the time of the Thompson & Hunt survey, collections made near the outlet of the Rantoul sewer ditch during warm weather contained an abundance of fish of 12 species (mostly the creek chub and silverjaw minnow; the stoneroller and Johnny darter also were common). However, no fish were found at this location during the cool periods of the year. The location is presently polluted by effluent from a disposal plant placed in operation in 1954. In August, 1959, the stream below the plant was foul and the bottom was covered with sludge. It contained a few fish that were seen but not identified. The stream was revisited the following May, at which time the white sucker, stoneroller, silverjaw minnow, creek chub, and sand shiner were taken.

The Chanute Air Force Base, in the vicinity of Rantoul, operates three treatment plants that pollute a small stream flowing eastward from the southern edge of the Base. A station on this small stream contained an abundant population of 14 species at the time of the Thompson & Hunt survey, but yielded only three creek chubs and a carp when we collected there in August of 1959. The following April, when we revisited the site, it was devoid of fish.

The influence of pollution on the East Branch extends downstream several miles. Two and one-half miles below the Rantoul disposal plant, the stream smelled foul and contained other evidence of sewage in October, 1959, when a collecting station was set up there. A few specimens of the creek chub, stoneroller, silverjaw minnow, bluntnose minnow, sand shiner, and spotfin shiner were taken at this station. Two miles below, in the mouth of a small creek that flows from the air base into the East Branch, fairly large numbers of fish were taken during the same month. At this second station, all of the species listed above were collected and, in addition, the white sucker, creek chubsucker, quillback, carp, and redfin shiner. The fact that conditions looked much better at the second station than above, in either the main creek or the small branch, suggested that the organic waste, after it had been digested and diluted, enriched the water to produce a large fish population.

Lower Salt Fork. — Thompson & Hunt considered the lower Salt Fork severely affected by pollution as far downstream as the Homer Dam near the county line; they collected only a small variety of species and found low populations at the stations in this area. In 1959, septic conditions occurred between St. Joseph and Sidney; however, between Sidney and the county line the stream appeared clear of pollution, although the water chemistry still reflected the upstream pollution, table 3. At five stations from which we took quantitative fish samples in this area, the populations were slightly below the average for streams of this size in the rest of the county, table 14.

Copper Slough, Phinney Branch.—Both branches of the small stream draining the west edge of Champaign were badly polluted in 1959. Copper Slough received industrial and domestic waste. It apparently was polluted in 1928, for Thompson & Hunt found no fish at their one station near Illinois State Route 10. Only the blackstripe topminnow was taken in Copper Slough in 1959.

In 1959, Phinney Branch received effluent from a small treatment plant located on its bank immediately above its confluence with Copper Slough. The effluent from this plant apparently prohibited existence of fish in this stream, although the pollution was probably less severe in 1959 than it was prior to the installation of the plant in 1956. At the junction of Phinney Branch and Copper Slough, a large variety of fishes was collected during the course of the 1959 survey. On February 27, 1960, no fish were seen at the junction of these two streams; perhaps the level of pollution from Copper Slough and Phinney Branch was such that it permitted the existence of fish in the lower reaches only during certain times of the year.

Upper Sangamon.—In 1959, pollution effluent from Gibson City flowed 6 miles south through Drummer Creek and entered the upper Sangamon. Domestic wastes from Gibson City and wastes from a packing plant and from a soybean mill caused fish kills in Drummer Creek and the upper Sangamon almost annually during recent decades. According to Thompson & Hunt, wastes from a canning factory at Gibson City caused the fish kill that they described. Such kills have extended downstream as far as Mahomet. The threat of severe pollution was reduced, but not eliminated, by the recent installation of a disposal plant at Gibson City for the treatment of domestic wastes.

Upper Kaskaskia.—Alteration of the natural water temperatures of a stream may be considered a type of pollution. West of Champaign, one-half mile south of Illinois State Route 10, the U. S. Industrial Chemical Company from time to time pumps large volumes of water from three wells into the Kaskaskia for use at plants near Ficklin, 20 miles downstream. The temperature of the well water is near 55 degrees F. On July 14, 1959, at 3:00 P.M., the stream temperature above these wells was 91 degrees, at the wells 60 degrees, and the water temperature remained subnormal for 5 miles below the wells. On February 2, 1961, at 10:00 A.M., when all other streams in the county were covered by heavy ice, the Kaskaskia was open for 6 miles below the wells. The water temperature was 51 degrees at the wells, 36.5 degrees 3.5 miles downstream, and 32.5 degrees 6 miles below the wells. Large aggregations of fish and heavy algal blooms occurred in the 2 miles of stream below the wells. Besides altering temperature and producing a more constant flow seasonally, the wells also reduced the sulfate, chloride, and hardness (as $CaCO_3$) of the water below that of any other natural waters examined in the county, table 3. Although species composition and the distribution of fish aggregations could conceivably be altered by the well water, no such evidence was available from our collections.

Chemistry of Polluted Waters

Pollution may drastically change the amount of dissolved chemicals in water. Samples taken on the East Branch of the Salt Fork north of St. Joseph, on the West Branch east of Urbana, and on the Salt Fork northwest of Homer, fig. 14, all show the influence of domestic and commercial wastes, table 3, and are characterized by high concentrations of ammonium, nitrate, phosphate, chloride, total dissolved minerals, and alkyl benzene sulfonate. No consistent relationship seems to exist between alkalinity or hardness and the degree of pollution. The most striking difference between the chemistry of the water in the East Branch, where a greater than average fish population was taken, and the chemistry of the water in the West Branch, where very few fish were taken, was in the level of phosphates and sulfates present. The West Branch contained nearly four times the concentration of phosphates and twice the concentration of sulfates found in the East Branch. Concentrations of phosphates in the West Branch were presumably due to the great amount of detergents that pass through the treatment plant of the Urbana-Champaign Sanitary District. Alkyl benzene sulfonate, one of the basic ingredients in most household detergents, was nearly twice as concentrated in the West Branch as in the East Branch.

Fish Anomalies Caused by Pollution

Many malformed fishes were taken from the West Branch of the Salt Fork above the sanitary disposal plant. Although fair numbers of individuals were taken in these collections, table 25, the fish were small in size and many of them had abnormally small, upturned mouths; certain fins were partially or entirely missing. The creek chub, bluntnose, and common shiner seemed to be especially affected. They may be the only species that can reproduce in the polluted water, and hence, in their embryonic development, they may have been influenced by toxic substances.

Fish Kills

Mention has been made of fish kills in Champaign County. A kill of fish has been observed annually for many years on the upper Sangamon River. Dead fish have been reported as far downstream as Mahomet. A severe kill occurred during the middle of August in 1959 while we were engaged in the third survey. Dead fish were found in the upper Sangamon from the mouth of Drummer Creek downstream as far as the town of Fisher. Along the banks 3 miles north of Fisher, 21 species were identified. Dead mussels, crayfish, tadpoles, and salamanders (*Necturus*) also were found. The proportion of the fish population killed by this pollutant was not known. The dead fish picked up and examined represented most of the species previously taken in our collections. In spite of the recurring kills, the disappearance of only one species is attributed to this pollution. A minnow (*Notropis amnis*), taken at three stations in the Sangamon near Fisher by Thompson & Hunt, seemingly no longer occurs in the county.

On the upper Kaskaskia, severe pollution introduced at a point just south of Champaign County near Ficklin has produced chronic toxic conditions and frequent fish kills. The Ficklin pollution probably blocks the upstream movements of certain species and thus influences the composition of the populations within Champaign County.

The East Branch has had several fish kills in recent years other than those caused by domestic pollution from Rantoul and Chanute Air Force Base. One such kill was said to have been caused by the accidental release of a large volume of gasoline into the stream. Another kill resulted from discharge into the stream of solutions used for cleaning aircraft.

On the West Branch, an occasional dead fish can be found, although so few fish occur in the area below the disposal plant that even if all were killed there would not be a noticeable number of dead individuals along the banks. Probably the fish found dead were individuals that moved into this area when water conditions were temporarily tolerable and were killed as conditions again became lethal.

In the lower Salt Fork, fish kills frequently have occurred below St. Joseph. These probably have been the result of overenrichment of the waters, where near-pollution conditions are usually present. Summer fish kills seem to be associated with periods of very low water levels and high temperatures; during such periods septic conditions develop. Often in the wintertime, blooms of green plants and animals develop that cause the death of fish over a long stretch of the river. Very heavy algal blooms developed during February and March of 1954. An abnormally low amount of suspended silt was in the water when there developed a tremendous green bloom composed mainly of *Euglena* sp. (similar to *E. sanguinea*) and a diatom, *Hantzschia amphioxus* (identification by Dr. P. C. Silva, then Associate Professor of Botany, University of Illinois). The organisms settled to the bottom of the stream each day after dark and blanketed the bottom materials. Many fish were seen gasping along the shoreline of the river and in small tributary water sources. Dead fish could be seen all along the river from St. Joseph as far downstream as Fairmount in Vermilion County. These water conditions not only killed many fish but caused the flesh of surviving fish to be unpalatable.

Ingression Into Polluted Waters

During the spring and early summer of 1960, we made a series of seine hauls at the West Branch stations sampled the previous September. These seine hauls indicated a certain amount of ingression of fishes into polluted water, table 27. The several species taken below the disposal plant were represented by very few individuals. The creek chub, bluntnose minnow, redfin shiner, and golden shiner were the species most frequently taken in these collections.

Reinvasion of a stream area by species once present is usually very rapid (Larimore, Childers, & Heckrotte 1960:269); if chemical conditions below the disposal plant were made suitable for the existence of fish, the population would quickly build up to what might be expected in streams of similar size.

Specific Tolerance to Pollution

The following species were most frequently found in the polluted water areas sampled in 1959: creek chub, carp, silverjaw minnow, bluntnose minnow, redfin shiner, golden shiner, stoneroller, green sunfish, sand shiner, common shiner, spotfin shiner, white sucker, creek chubsucker, topminnow, Johnny darter, and hornyhead chub. The finding of a particular species in a polluted area did not necessarily mean that this species was more pollution-tolerant than other species. Species found in a polluted area may have been unusually vagile, moving into the area during periods of improved water conditions; equally pollution-tolerant species might have been absent because they did not occur in the drainage system, because suitable habitat was not available, or because they were more sedentary in habits. The above list of pollution-tolerant species contains most of the species listed as tolerant by Thompson & Hunt.

DISTRIBUTION AND WATER ENRICHMENT

Stream enrichment is a vaguely defined condition in which some of the dissolved chemical constituents of the water are greater in amount than would normally occur from contact with the soil in a particular drainage system or region. Enrichment of a body of water should result in greater productivity of aquatic organisms. However, because aquatic organisms have rather specific requirements, enrichment may produce conditions inimical to their very existence. Enrichment to some organisms is pollution to others.

Champaign County streams are enriched by minerals leached from the soils of the drainage area, by fertilizers added to soils for increased crop production, by wastes from livestock, and by domestic sewage. Wastes from commercial operations could also contribute enriching matrials, although no instance of such enrichment is known to occur in this county.

Natural Soil Fertility

The soils of Champaign County are unusually fertile and contribute dissolved nutrients to the streams draining them. The chemical composition of the waters, table 3, has been discussed previously.

Thompson & Hunt assumed that the size of a fish population was related to soil fertility because they found the largest concentration of fishes in the East Branch of the Salt Fork River, which flows through an area that they regarded as more fertile than any other in the county. Presently available information on the soils of Champaign County does not indicate that the streams in this drainage flow through an area more fertile than other drainage areas of the county. At only three of our collecting stations on the East Branch was the weight of fish per 100 square yards much greater than the average for the county, tables 14 and 26.

Alkalinity and total hardness have often been related to high productivity in natural waters. All of the streams in the county are slightly alkaline and rather hard. The water in one of the two main streams in the East Branch drainage, the Spoon River, is the hardest in the county and one of the most alkaline, whereas water in the other stream is the least alkaline and near average in hardness, table 3. Because of differences in chemical composition of these streams, which produced several large fish collections and were regarded by Thompson & Hunt as especially fertile, it is difficult to relate fish productivity to soil or water fertility. The differences between these streams appear to be more the result of domestic pollution than of soil characteristics in the drainage area.

Fertilizers on the Watershed

Commercial fertilizers are used by farmers on virtually all of the croplands of Champaign County. The amount of fertilizer that enters the streams is influenced by the natural soil chemistry, the soil permeability, the land use, the kind and amount of fertilizer applied, and other factors that make an exact determination difficult.

Large amounts of organic fertilizer in the form of livestock manure are applied by farmers to most of the watersheds. The droppings of grazing cattle and hogs are deposited in pastures, often along stream banks, and sometimes actually in the streams. In some areas, manure contributes substantially to the fertility of the streams. An excess of fertilizer can cause fish mortality during the hot summer months when the water levels are unusually low, but, in Champaign County, instances of damage caused by excess amounts of livestock manure are probably rare. Damage is done by livestock when the animals break down stream banks, permitting excessive amounts of silt to enter water courses.

Domestic Sewage

Domestic sewage can be related to stream productivity in several places in Champaign County. Thompson & Hunt in 1928 found a fish population in the East Branch apparently benefiting from enrichment of stream water by the domestic sewage of Rantoul. At that time, Rantoul did not treat sewage but allowed it to run through an open ditch where, during warm weather, it was well digested before entering the East Branch. On revisiting the station during a cooler part of the year, Thompson & Hunt found that the raw sewage was not digested in the open ditch but that it entered the East Branch as toxic material that eliminated fish for several miles downstream.

At present, there is evidence of enrichment of the East Branch by domestic sewage from Rantoul and Chanute Air Force Base. For several miles below the outlets, this sewage is toxic to fish most of the time. Farther downstream, large populations of a wide variety of fishes benefit from the end-products of the sewage that has been digested upstream. At one station with 41 square miles of drainage, 7.2 miles below the Rantoul disposal plant and approximately 2 miles below the entrance of the badly polluted stream from Chanute, the collection per 100 square yards amounted to 1,337 fish weighing more than 9 pounds. At another station with 73 square miles of drainage, 4.5 miles farther downstream, the collection per 100 square yards amounted to 1,331 fish weighing more than 10.5 pounds. These figures, three to four times the county averages, table 14, represented an area a few miles below the badly polluted area in which very few fish were found.

A fish population possibly benefiting from stream enrichment was taken in the upper Sangamon River about a mile below the mouth of Drummer Creek, which receives pollution from several sources in Gibson City. In this population, the numbers of individuals of the 22 species represented were low, but their sizes were sufficiently large to make the collection average 5.6 pounds per 100 square yards, a weight nearly twice that for most other streams of this size (193 square miles of drainage) in the county, table 14.

An instance that may be considered partial enrichment was found west of Champaign on Phinney Branch at the junction of Copper Slough. The upper regions of both Phinney Branch and Copper Slough were polluted, but where they converge 20 species were taken; the collection averaged 2.6 pounds per 100 square yards of drainage. Although 20 is an unusually high number of species for streams of this class (16 square miles of drainage) in the county, the weight was not much above average, table 14.

The Salt Fork from St. Joseph to the county line was the longest stretch of stream in the county enriched by upstream sewage. However, our collections failed to indicate any desirable effects of the enrichment.

Where fishes are benefiting from enrichment of the water, they may be existing under conditions that with very slight changes in chemical balance and concentration can quickly become toxic to them. Our data show that when desirable enrichment changes to undesirable pollution the effects on a fish population are first a reduction in the number of species, then a reduction in the total weight, and finally a reduction in the number of individuals.

FISHERIES

The network of streams and a scattering of artificial ponds and lakes provide a considerable amount of fishing water in Champaign County. All of the streams, except the Little Vermilion and Embarrass, are listed in the Game and Fish Codes as fish preserves; that is, fishing is restricted to hook-and-line methods, or to minnow seining and spearing as provided by the Game and Fish Codes. Public access to most of the streams is provided by the system of section-line roads, and fishing is generally heaviest near bridges. All the waters as well as the stream banks are privately owned; fishermen must obtain landowners' consent to enter the property.

Sport Fishing

Approximately 20 of the 90 species in the annotated list of the fishes of Champaign County are commonly taken by hook-and-line fishing. However, Dr. Marcus S. Goldman has caught 38 species. The 189 miles we have classed as Rivulets and Small Creeks provide satisfactory angling only for small boys in quest of chubs, sunfishes, or bullheads. The 176 miles of Large Creeks provide good fishing for anglers interested in catching chubs, sunfishes, bullheads, and, in the spring, a variety of suckers. The 58 miles of Small Rivers produce large numbers of suckers, sunfishes, bass, carp, and catfishes. The lower Sangamon River is an especially good fishing area for channel catfish, suckers, and carp, and, according to Dr. Goldman, offers a better opportunity for angling than any other stream in the county. The lower Salt Fork is good for suckers and carp; channel catfish become important a few miles before the stream leaves the county. The Middle Fork in Champaign County produces three species of bass and the channel catfish.

Creek chubs, hornyhead chubs, black bullheads, yellow bullheads, several sunfishes, and many species of suckers can be taken in most streams of the county. The most commonly used baits are worms, minnows, crayfish, and especially prepared cheese baits, blood baits, and doughballs; relatively little casting is done with artificial lures.

Approximately 125 ponds and small lakes provide angling. These waters are formed by artificial dams and by flooded gravel and borrow pits. Most of the ponds are privately owned.

The fishes commonly found in these ponds are the bluegill, green sunfish, redear sunfish, orangespotted sunfish, warmouth, black crappie, white crappie, largemouth bass, black bullhead, yellow bullhead, channel catfish, golden shiner, and bluntnose minnow.

Commercialized Sport Fishing

Three privately owned lakes in Champaign County have been licensed to operate as daily fee-fishing ponds. Great numbers of fish are purchased from commercial fishermen and fish dealers along the Mississippi and Illinois rivers, on some northern lakes, and even on Lake Erie as far east as Ohio. These fish are hauled alive by truck and released in the fishing ponds at intervals during the fishing season. Anglers pay a daily fee to fish. Because the fish are of many species and because some are brought from distant waters, the ponds are potential sources of species new to the streams of the county. The following species have been taken from Champaign County fee-fishing ponds: bowfin, bluegill, green sunfish, white crappie, yellow bass, carp, channel catfish, brown bullhead, yellow bullhead, black bullhead, largemouth bass, quillback, gizzard shad, goldfish, and a few minnows that probably were not deliberately introduced by the pond owners.

Bait Collecting

Large numbers of minnows suitable for fish bait may be taken from many reaches of Champaign County streams. Crayfish also are taken from the streams.

Although in 1959 there were no licensed wholesale minnow dealers in Champaign County, there were eight retail minnow dealers who sold minnows to sport fishermen. Their minnow supplies were either purchased from sources outside the county or were seined by the dealers themselves from local streams. Because of the great labor and cost involved in procuring a sufficient number of minnows from local streams, most dealers found it more economical to purchase stocks from wholesale dealers.

Many fishermen take relatively small numbers of minnows for their own use. They may take bait from the streams without a commercial fishing license in seines not larger than 6 feet deep and 20 feet long and having a mesh of one-half inch or less. Many fishermen have favorite minnow "holes" where they can seine enough minnows for a 1-day fishing trip. Such small-scale bait collecting is a justifiable use of minnows and does not endanger the natural populations.

SUMMARY

1. Two investigations of fishes in the streams of Champaign County, Illinois, investigations approximately 30 years apart (modal years 1899 and 1928), provided an incentive for a third investigation, in 1959, aimed at evaluating the effects of ecological changes that occurred over a period of approximately 60 years in an area that included both intensive farming and urbanization.

2. In less than a century, most of Champaign County was converted from marshy prairie to well-drained farmland. In recent years, population growth and

industrial development have usurped a considerable acreage of the farmland.

3. Draining and dredging reduced the water-holding capacity of the watersheds, resulting in a lower water table and in extreme fluctuations in stream flow. Canalization altered stream courses and habitats and produced more uniformity in stream environments.

4. Late in the nineteenth century, most of the marshes and natural ponds were eliminated; many drainage ditches were created. During the 30 years ending in 1959, the environmental trends in the streams were toward a decrease in depth and an increase in width; a decrease in gravel substrate, an increase in silt, and an increase in sand; a decrease in aquatic vegetation and an increase in overhanging vegetation.

5. Ninety species of fishes were included in the annotated list for Champaign County; 74 of these were taken in 1959 or subsequently. Seven of the 90 were introduced species; the remaining 83, some of them no longer in the county, were native.

6. Sixteen species, the introductions excluded, showed a decided increase in occurrence (number of collecting stations and number of stream systems in which they were found) within the county during the 60-year period of study; 15 other species showed a decided decrease in occurrence. Many species showed little change in occurrence, despite the great changes that took place in the stream habitats.

7. During the early part of the present century, the Salt Fork drainage contained a greater number of species than any other drainage in Champaign County; it was followed by the Sangamon, Middle Fork, Kaskaskia, and Embarrass. Subsequently, the Salt Fork and Sangamon exchanged rank. In 1959, the Sangamon contained the greatest number of species restricted to one drainage; the Embarrass had no species that occurred in that stream exclusively.

8. Much greater changes in species composition occurred in Champaign County streams during the first 30 years of the twentieth century than during the second 30 years. During the first 30-year period, the greatest changes occurred in the Middle Fork and Sangamon drainages; during the second 30-year period, the greatest changes occurred in the Kaskaskia and Salt Fork drainages.

9. Champaign County streams were classified as rivulets and small creeks, large creeks, and small rivers. Both large creeks and small rivers contained the following habitats: sand and fine gravel riffles; gravel and boulder or rubble riffles; shallow, firm-bottomed pools; and deep, mud-bottomed pools. Each habitat was found to have characteristic species of fishes.

10. Each factor in the habitat of a species was expressed mathematically by correlating the numbers and weights of each species taken in quantitative samples with the numerical value for each of 13 different ecological factors.

11. Significant degrees of association, some of which were unexpected, were found between the numerical abundance of *Notropis dorsalis* and *Ericymba buccata, Notropis chrysocephalus* and *Erimyzon oblongus,* and *Catostomus commersoni* and *Phenacobius mirabilis.* Less significant associations were found between each of these species and several other species and between a few other pairs of species. A mutual dependence upon certain ecological conditions, rather than a direct interdependence between species, appeared to account for the associations found in Champaign County.

12. The average number of species per collecting station and the average number of fish per 100 square yards of water were somewhat greater in 1959 than in 1928. The most pronounced differences in the number of fish per unit area occurred in the Middle Fork drainage (high in 1928, low in 1959) and the Embarrass (low in 1928, high in 1959). The number of pounds of fish per acre of water was found to be 124.4 in 1959; it had been estimated by Thompson & Hunt to be 150 in 1928. The number of pounds of fish per 100 square yards of water in 1959 averaged 2.6, ranging from 0.9 in the Kaskaskia to 5.1 in the Middle Fork drainage.

13. The following generalizations between fish distribution and stream size, as postulated by Thompson & Hunt (1930) following the 1928 investigation, were in general borne out in the 1959 study: the

number of species per station increased downstream; the actual number of fish per unit area decreased downstream; and, with a decrease in the number of individuals downstream, there was a corresponding increase in their average size, so that the total amount of fish flesh per unit area was nearly constant. Thompson & Hunt's statement that fishes exhibit frequencies of occurrence that vary with stream size in a consistent and definite manner for each species was not substantiated with the 1959 data. Their hypothesis that the amount of fish flesh per unit of water was directly related to fertility of the water was neither confirmed nor disproved by the 1959 data, probably because all streams of the county were of nearly equal fertility.

14. The degree of stream pollution in Champaign County was greater in 1928 than in 1899, and greater in 1959 than in 1928. Although certain types of pollutants common in 1899 and 1928 no longer existed in 1959, other types had replaced them. The large and increasing volume of treated effluents limited aquatic life in many areas of Champaign County streams at the time of the third survey. Pollution had caused a decline, even elimination, of fish in some reaches.

15. In 1959, chronic pollution in Champaign County was found to occur in the Boneyard, parts of the East Branch and West Branch of the Salt Fork, the lower Salt Fork, Copper Slough and Phinney Branch, the upper Sangamon, and the upper Kaskaskia. Some of these areas had been polluted for many years; others had recently become polluted.

16. Champaign County streams are enriched by natural soil fertility and a variety of introduced substances. Evidence was found in 1959 that certain fish populations were benefiting from enrichment. Slight changes in chemical balance and concentration may quickly convert enriched areas to polluted ones.

17. Champaign County contains a considerable amount of water useful for fishing. In addition to the streams, there are farm ponds, artificial lakes, and fee-fishing ponds available. Public access to the fishing sites is generally adequate, although streams are privately owned and landowners' permission must be obtained. Approximately 20 of the 90 species of fish known in the county are commonly taken by angling. Noncommercial minnow seining for bait is a justifiable use of the local fauna and does not jeopardize local minnow populations.

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SPECIES DISTRIBUTION MAPS

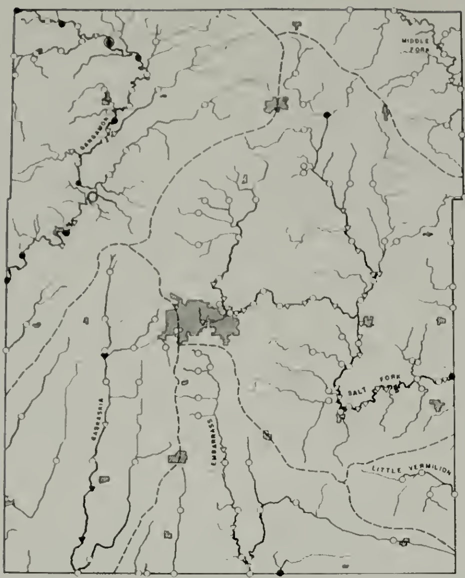

Fig. 15.—*Dorosoma cepedianum.*

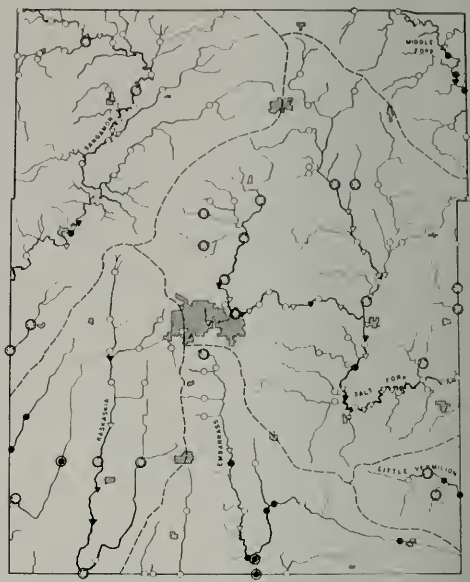

Fig. 16.—*Esox americanus.*

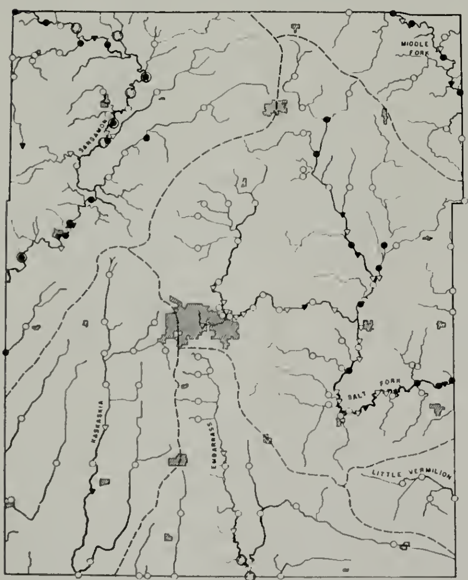

Fig. 17.—*Carpiodes cyprinus.*

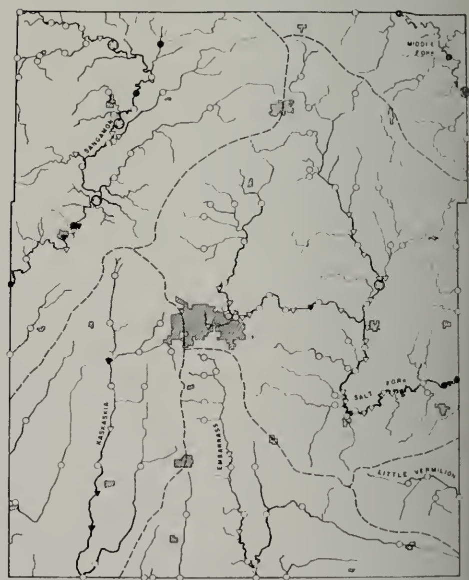

Fig. 18.—*Carpiodes velifer.*

Distribution of Champaign County fishes as determined by three surveys at approximately 30-year intervals.
Open triangle: collecting station of Forbes & Richardson; indicated species not collected.
Solid triangle: collecting station of Forbes & Richardson; indicated species collected.
Small open circle alone: collecting station of Thompson & Hunt and also, if extant in 1959, collecting station of Larimore & Smith; indicated species not collected at this station.
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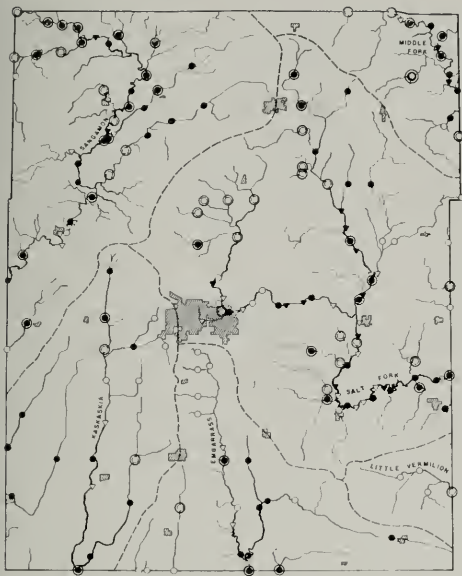

Fig. 19.—*Catostomus commersoni.*

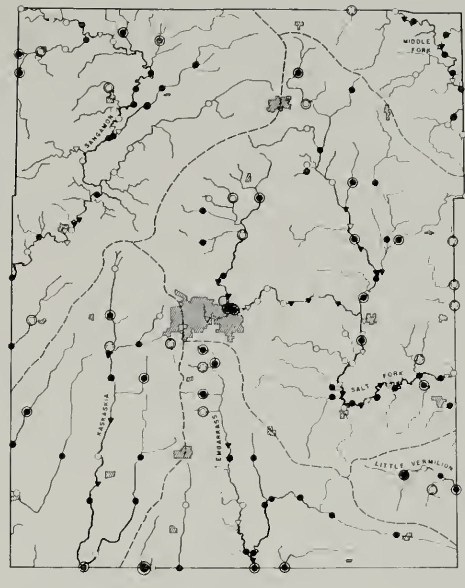

Fig. 20.—*Erimyzon oblongus.*

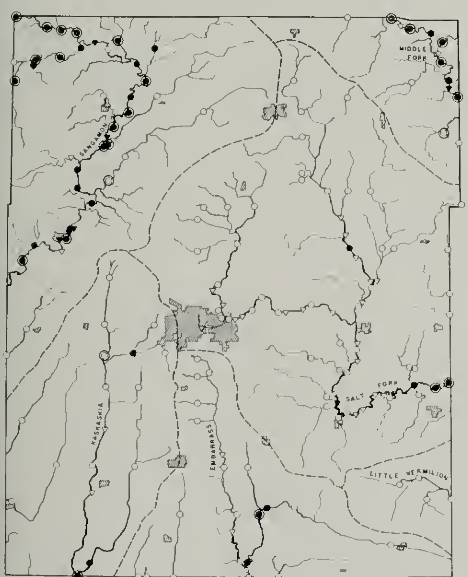

Fig. 21.—*Hypentelium nigricans.*

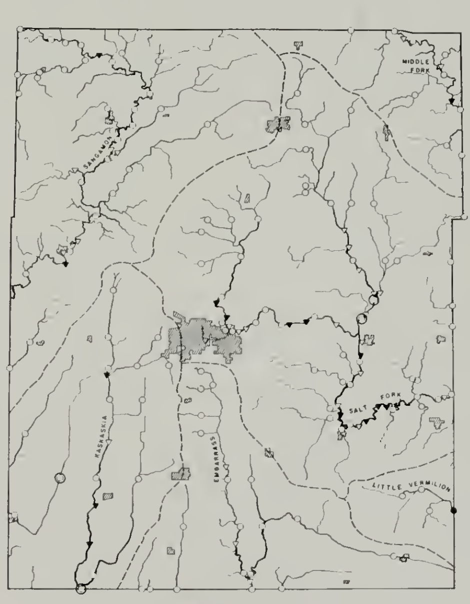

Fig. 22.—*Minytrema melanops.*

Distribution of Champaign County fishes as determined by three surveys at approximately 30-year intervals.

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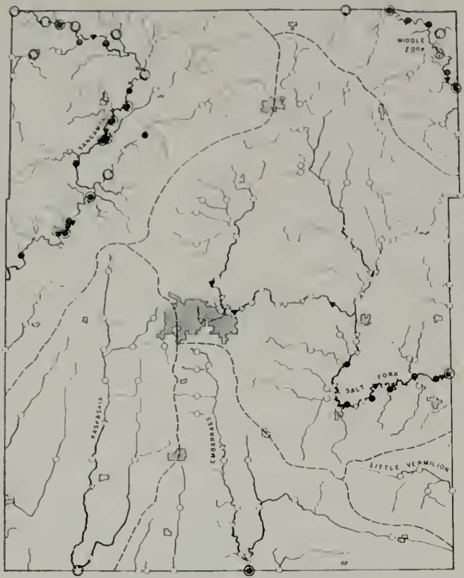

Fig. 23.—*Moxostoma erythrurum.*

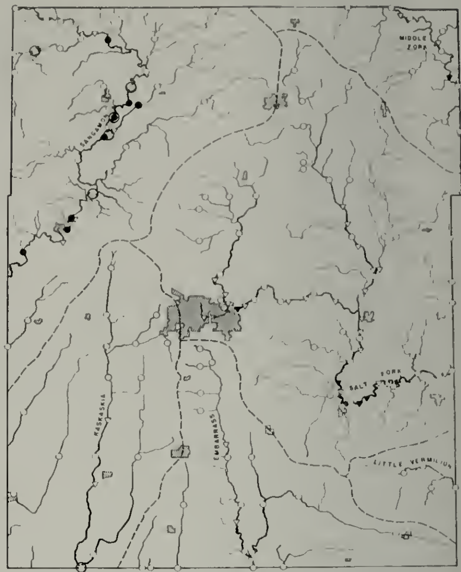

Fig. 24.—*Moxostoma macrolepidotum.*

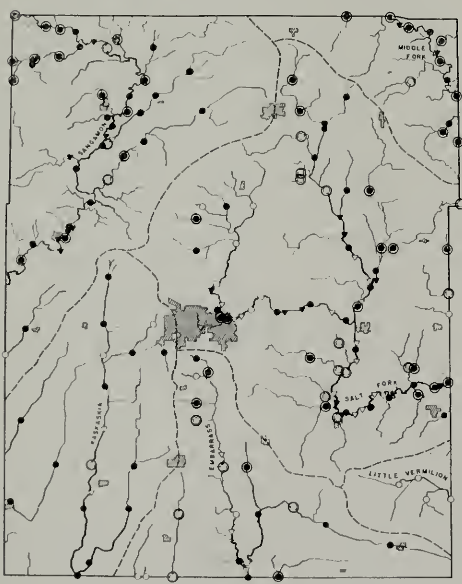

Fig. 25.—*Campostoma anomalum.*

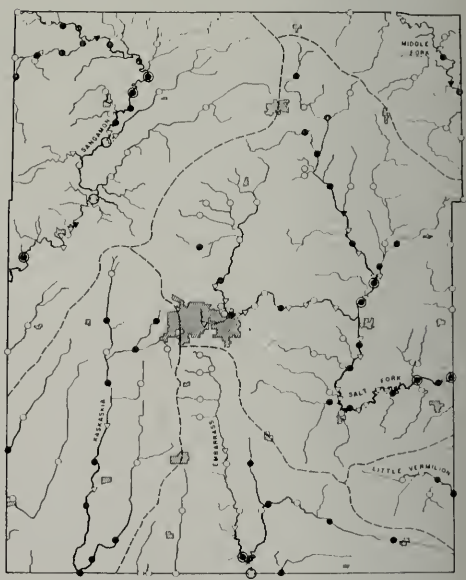

Fig. 26.—*Cyprinus carpio.*

Distribution of Champaign County fishes as determined by three surveys at approximately 30-year intervals.

Open triangle: collecting station of Forbes & Richardson; indicated species not collected.

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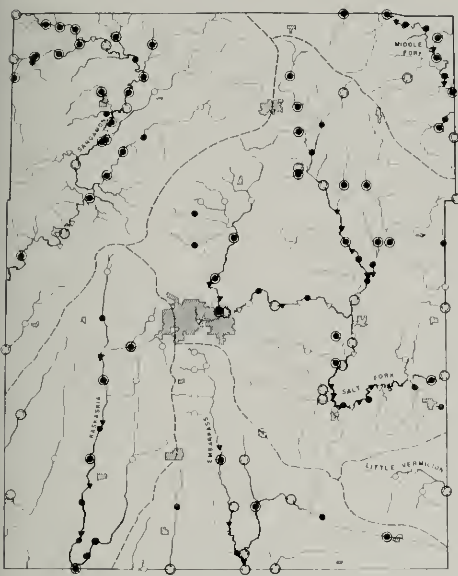

Fig. 27.—*Ericymba buccata.*

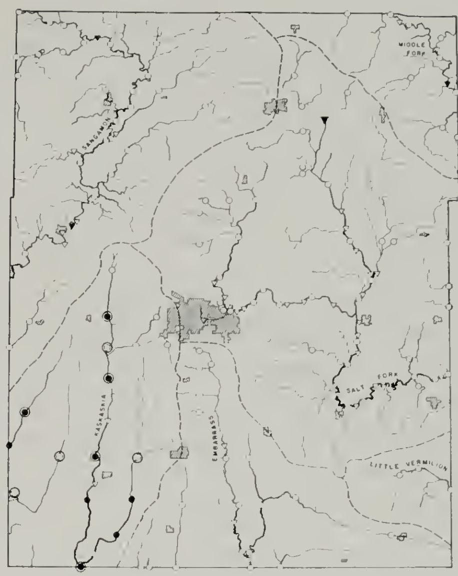

Fig. 28.—*Hybognathus nuchalis.*

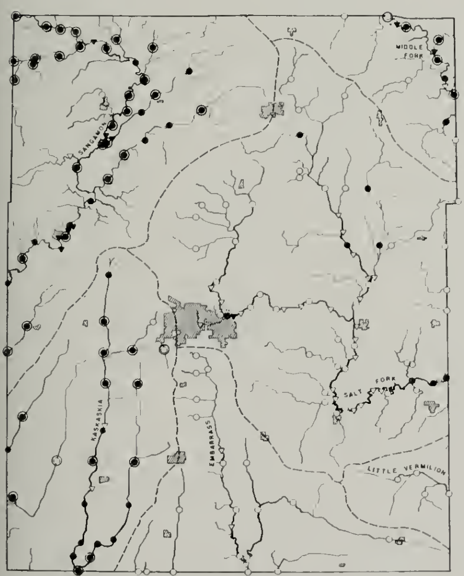

Fig. 29.—*Hybopsis biguttata.*

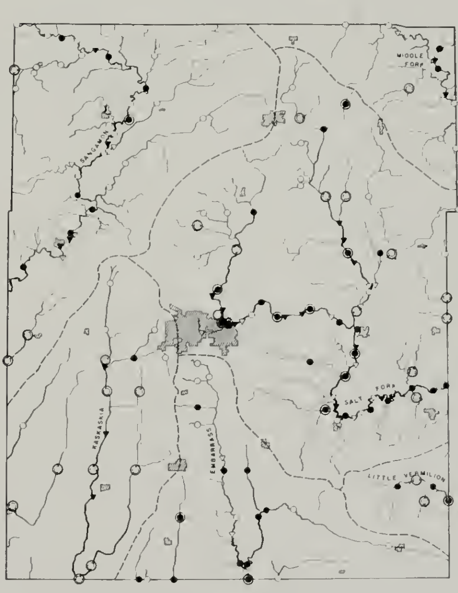

Fig. 30.—*Notemigonus crysoleucas.*

Distribution of Champaign County fishes as determined by three surveys at approximately 30-year intervals.
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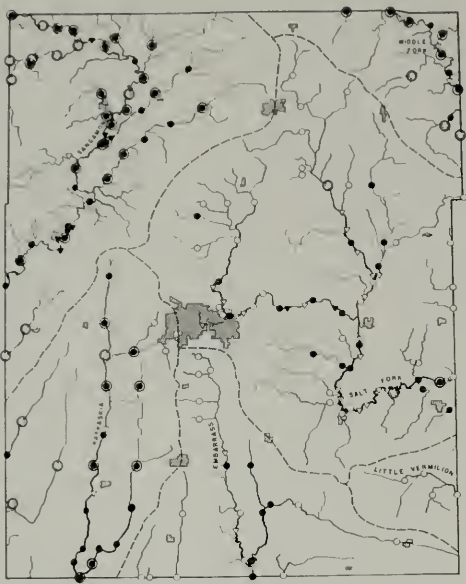

Fig. 31.—*Notropis chrysocephalus.*

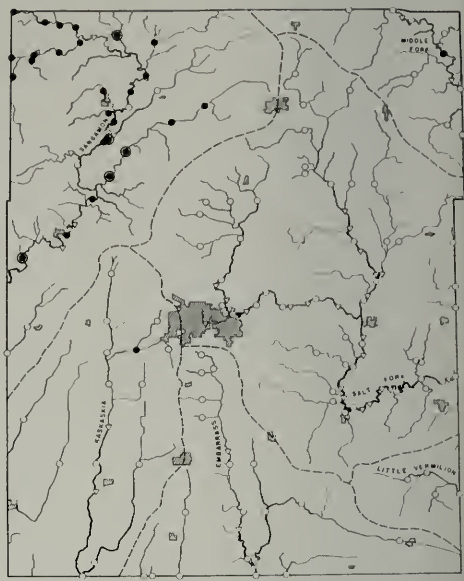

Fig. 32.—*Notropis dorsalis.*

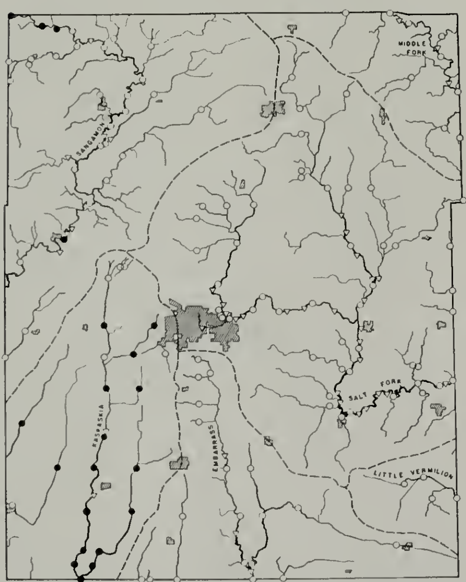

Fig. 33.—*Notropis lutrensis.*

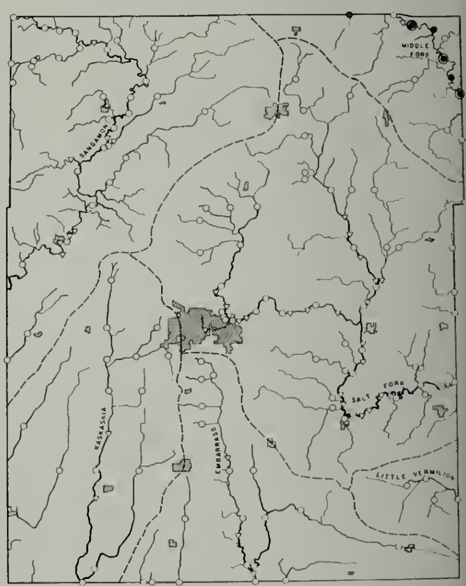

Fig. 34.—*Notropis rubellus.*

Distribution of Champaign County fishes as determined by three surveys at approximately 30-year intervals.

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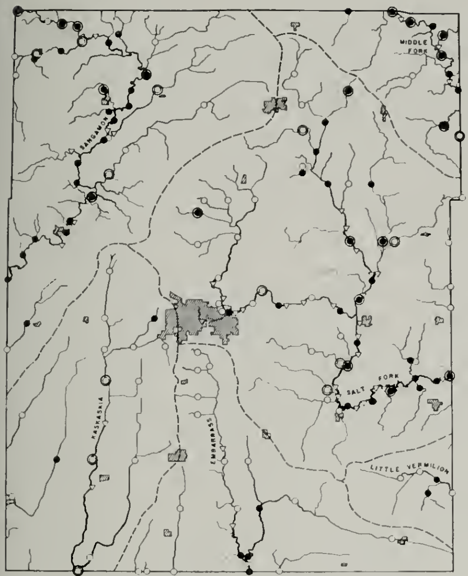

Fig. 35.—*Notropis spilopterus.*

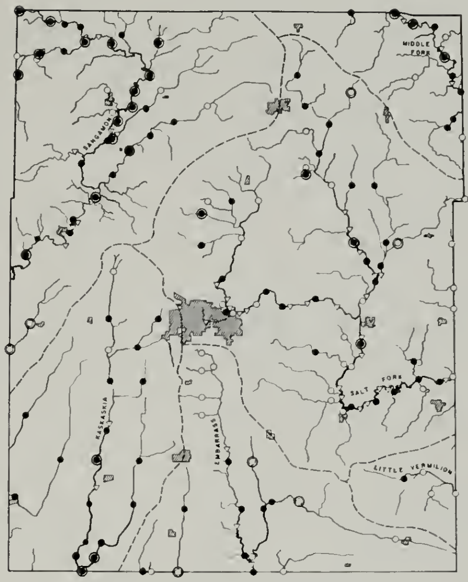

Fig. 36.—*Notropis stramineus.*

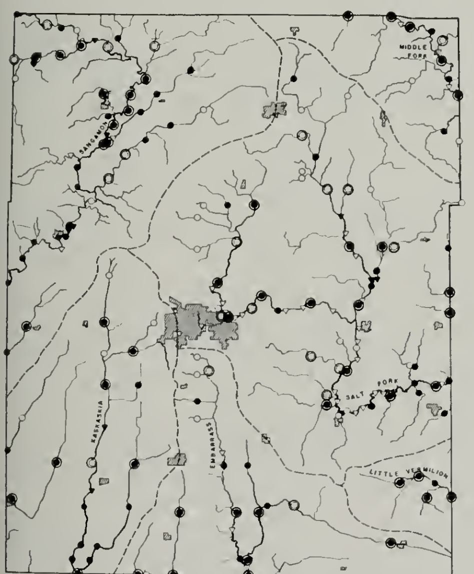

Fig. 37.—*Notropis umbratilis.*

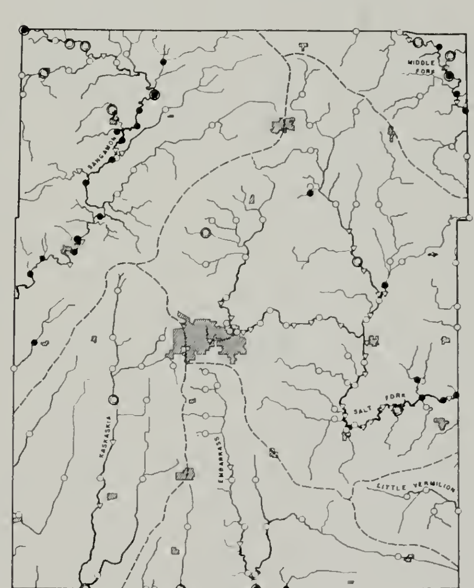

Fig. 38.—*Notropis whipplei.*

Distribution of Champaign County fishes as determined by three surveys at approximately 30-year intervals.
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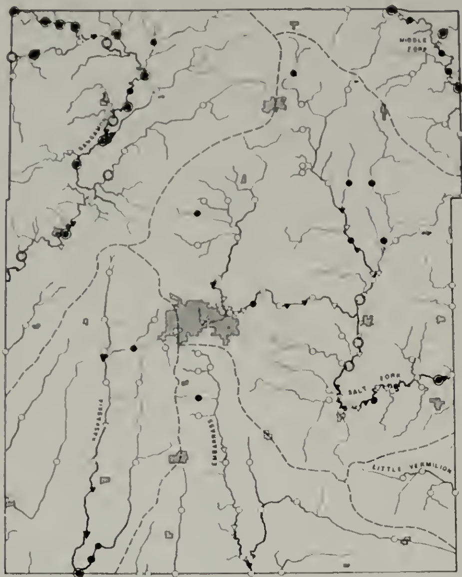

Fig. 39.—*Phenacobius mirabilis.*

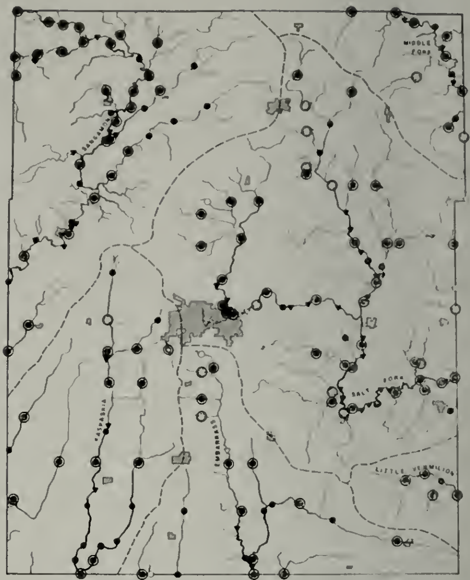

Fig. 40.—*Pimephales notatus.*

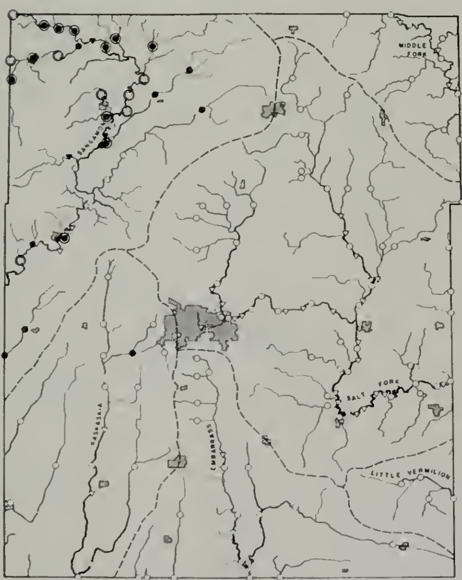

Fig. 41.—*Pimephales promelas.*

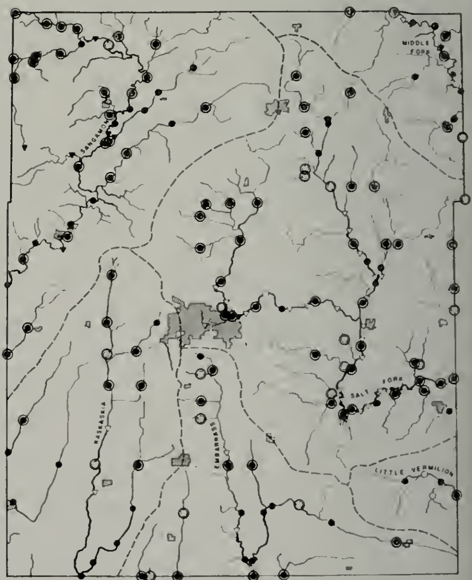

Fig. 42.—*Semotilus atromaculatus.*

Distribution of Champaign County fishes as determined by three surveys at approximately 30-year intervals.
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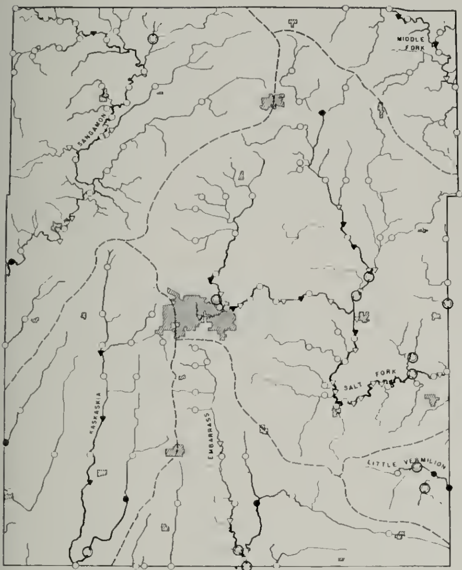

Fig. 43.—*Ictalurus melas.*

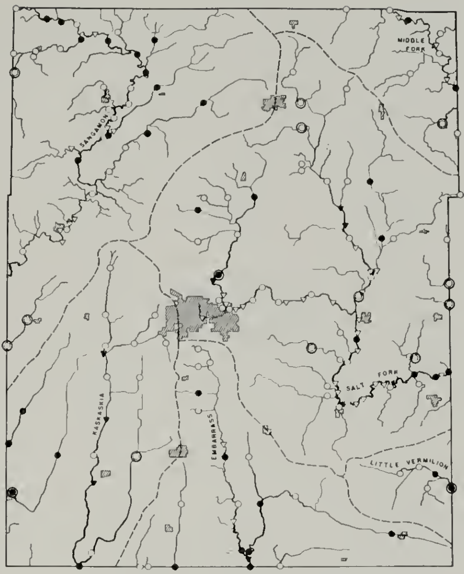

Fig. 44.—*Ictalurus natalis.*

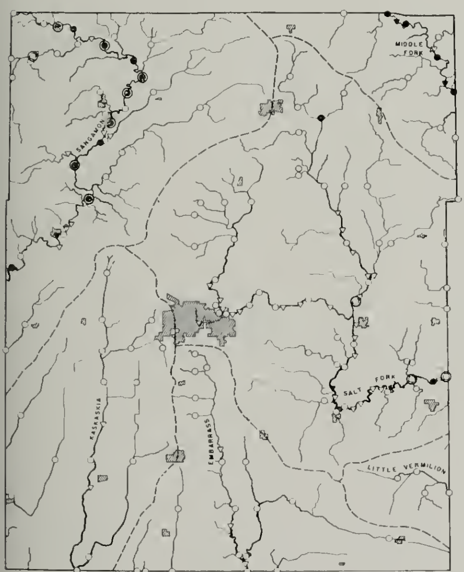

Fig. 45.—*Ictalurus punctatus.*

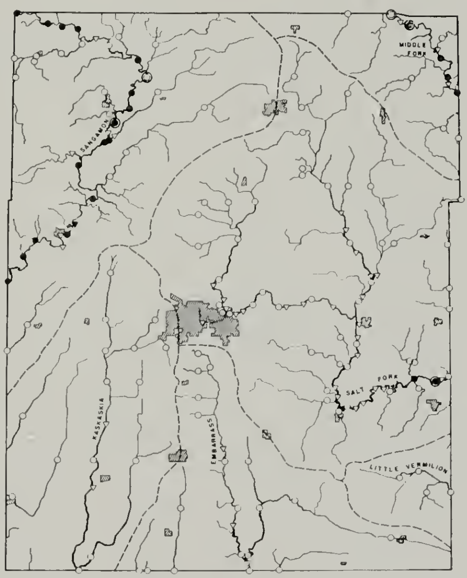

Fig. 46.—*Noturus flavus.*

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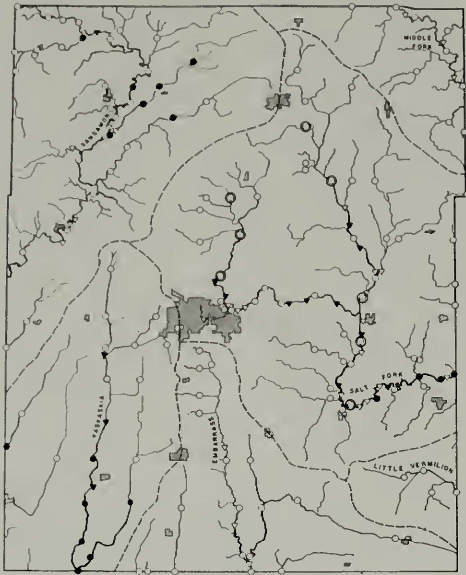

Fig. 47.—*Noturus gyrinus.*

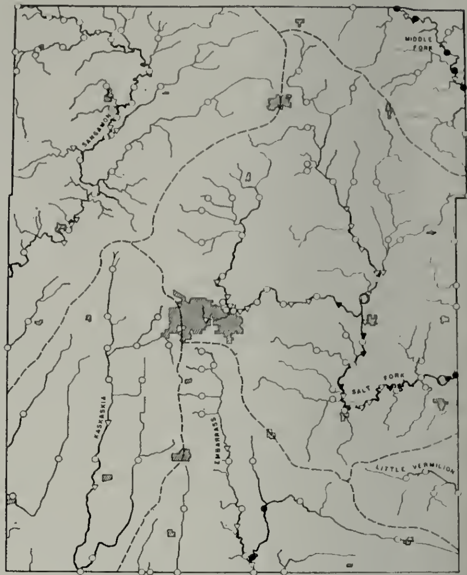

Fig. 48.—*Noturus miurus.*

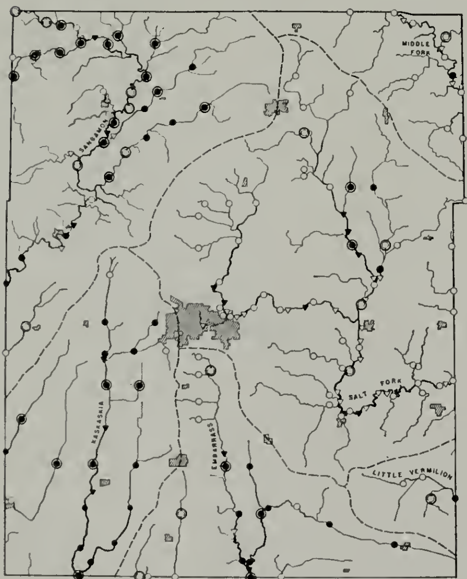

Fig. 49.—*Fundulus notatus.*

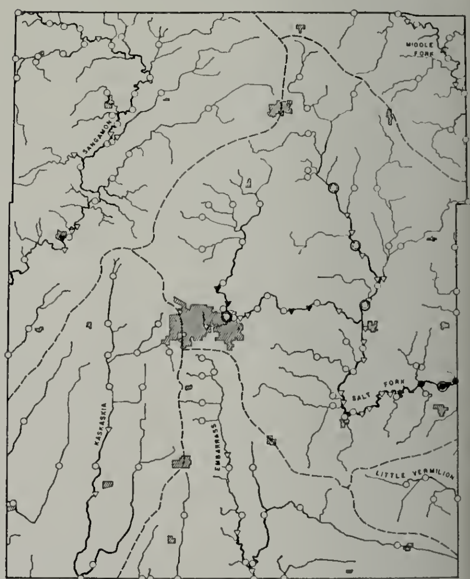

Fig. 50.—*Labidesthes sicculus.*

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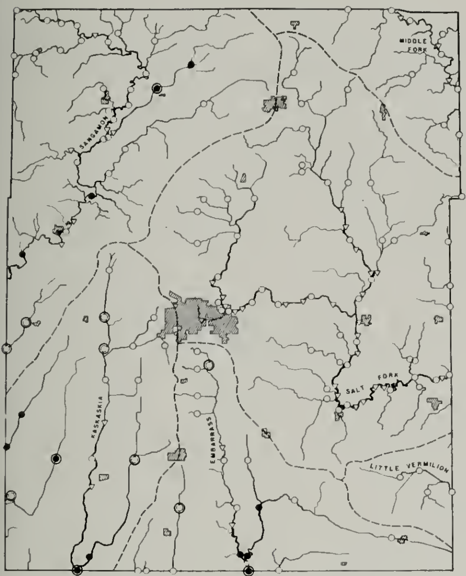

Fig. 51.—*Aphredoderus sayanus.*

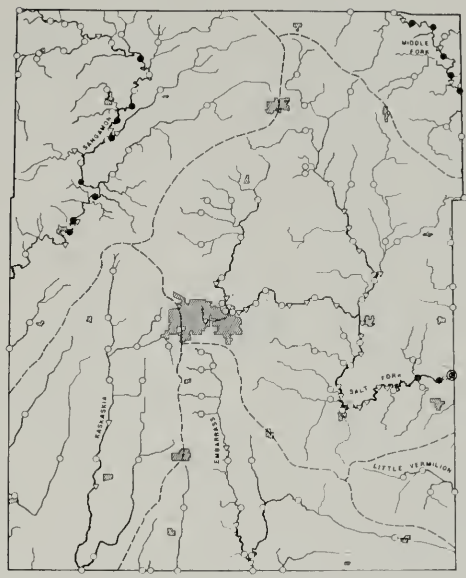

Fig. 52.—*Ambloplites rupestris.*

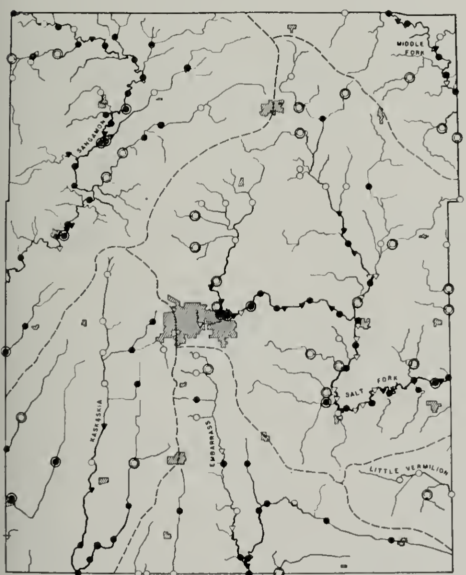

Fig. 53.—*Lepomis cyanellus.*

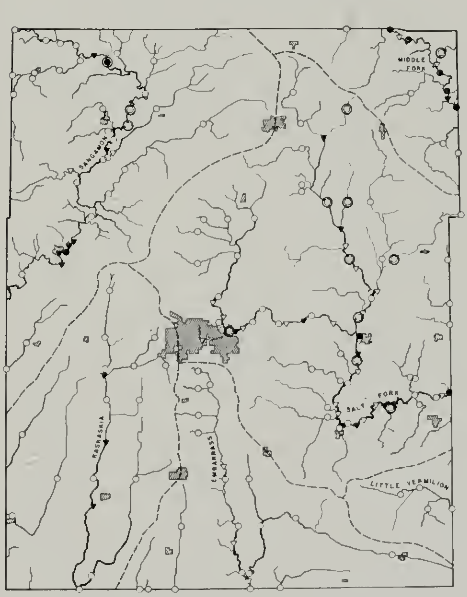

Fig. 54.—*Lepomis humilis.*

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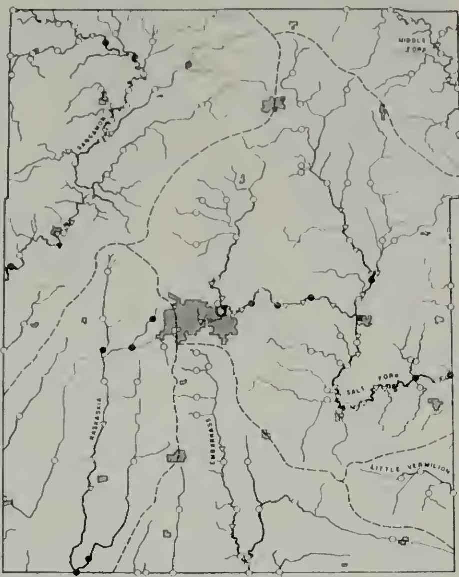

Fig. 55.—*Lepomis macrochirus.*

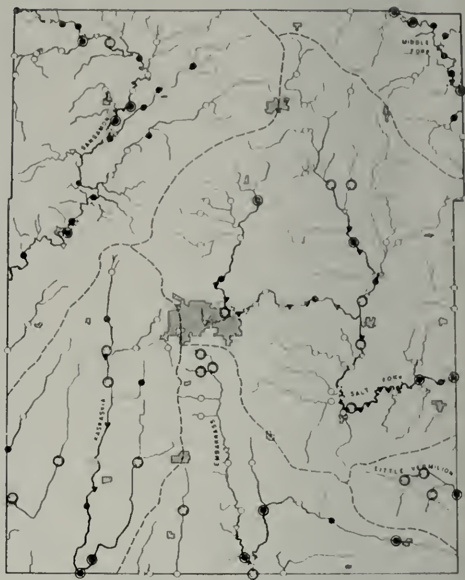

Fig. 56.—*Lepomis megalotis.*

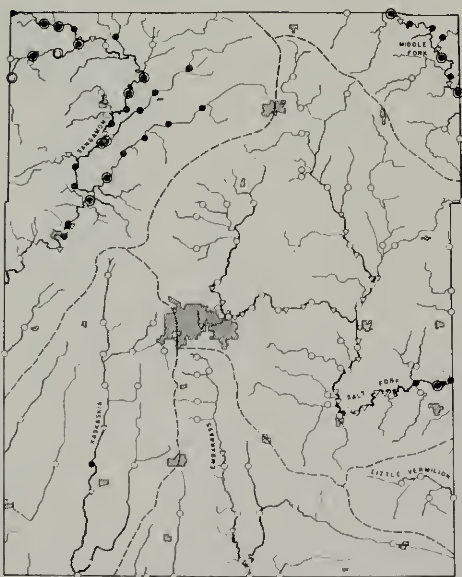

Fig. 57.—*Micropterus dolomieui.*

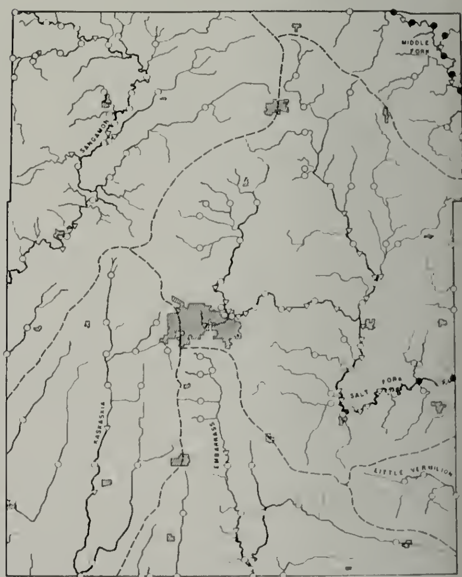

Fig. 58.—*Micropterus punctulatus.*

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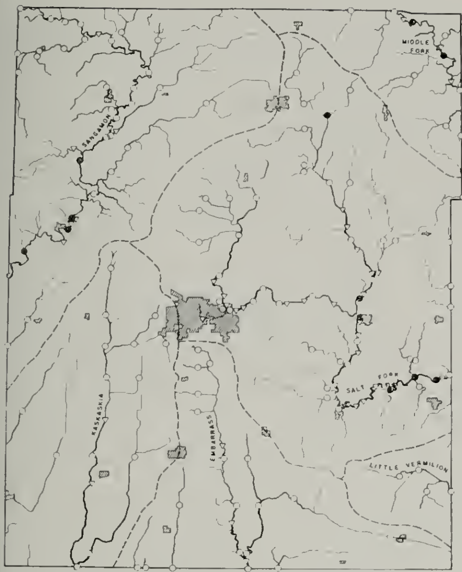

Fig. 59.—*Micropterus salmoides.*

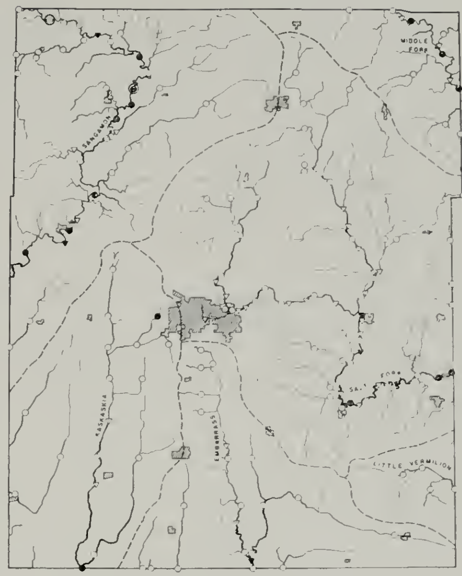

Fig. 60.—*Pomoxis annularis.*

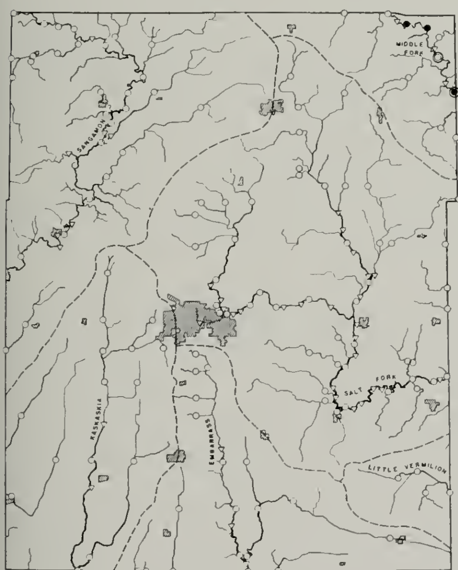

Fig. 61.—*Ammocrypta pellucida.*

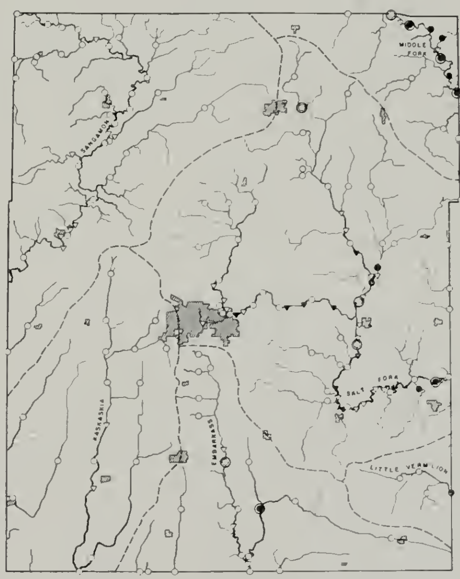

Fig. 62.—*Etheostoma blennioides.*

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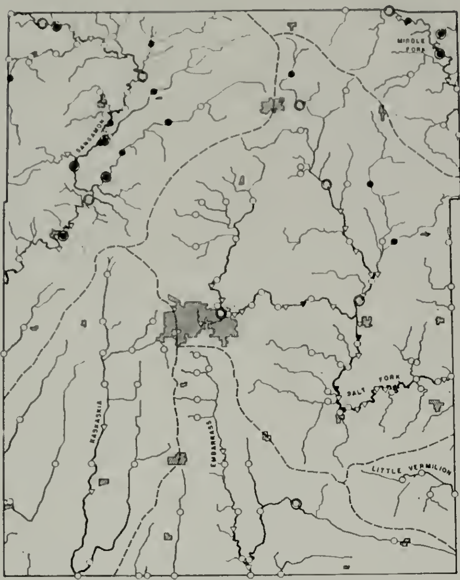

Fig. 63.—*Etheostoma flabellare.*

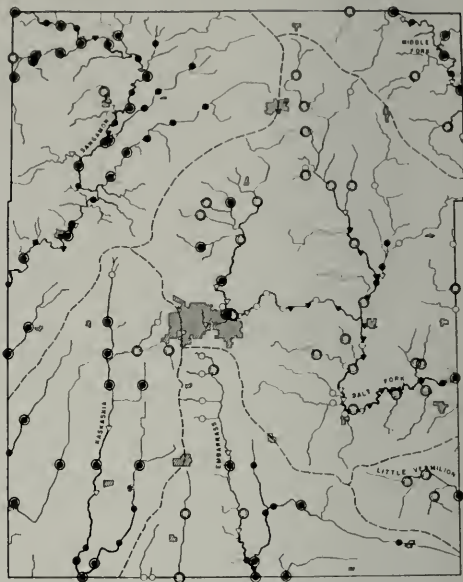

Fig. 64.—*Etheostoma nigrum.*

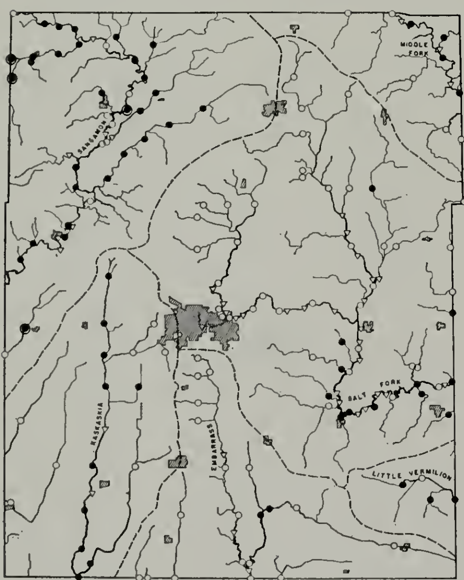

Fig. 65.—*Etheostoma spectabile.*

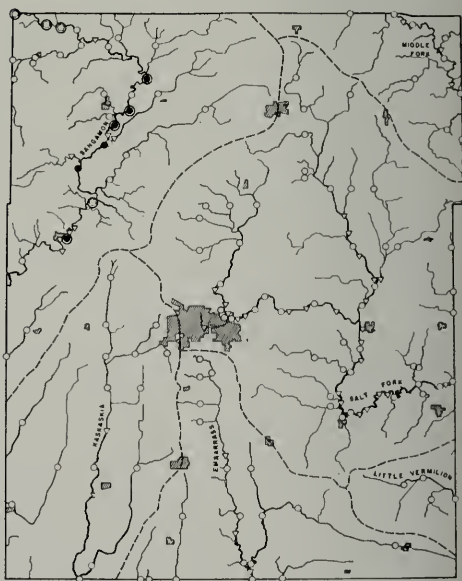

Fig. 66.—*Etheostoma zonale.*

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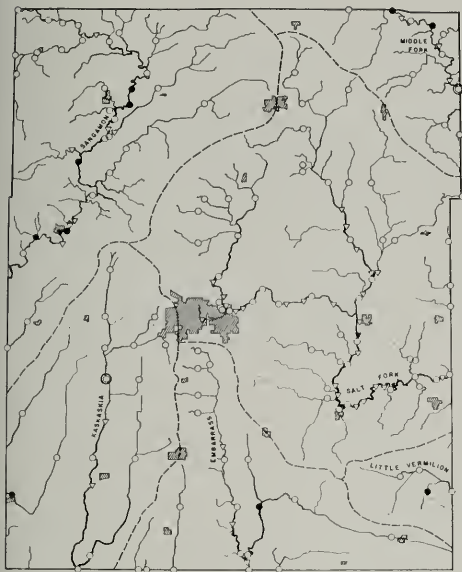

Fig. 67.—*Percina caprodes.*

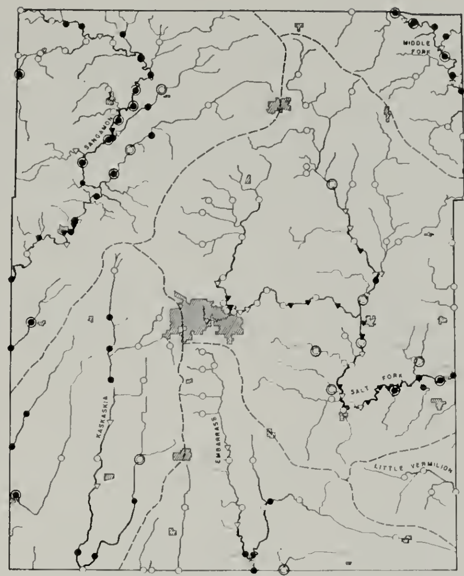

Fig. 68.—*Percina maculata.*

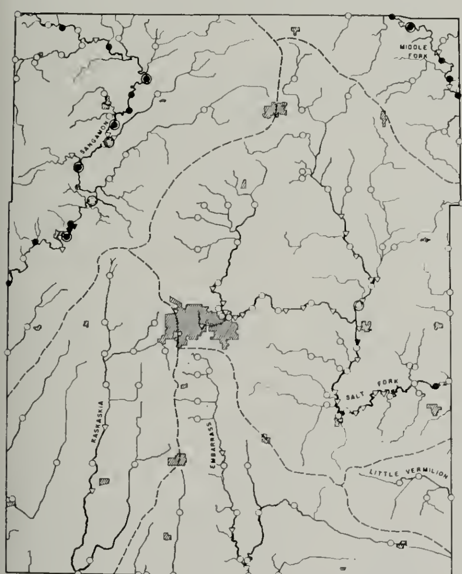

Fig. 69.—*Percina phoxocephala.*

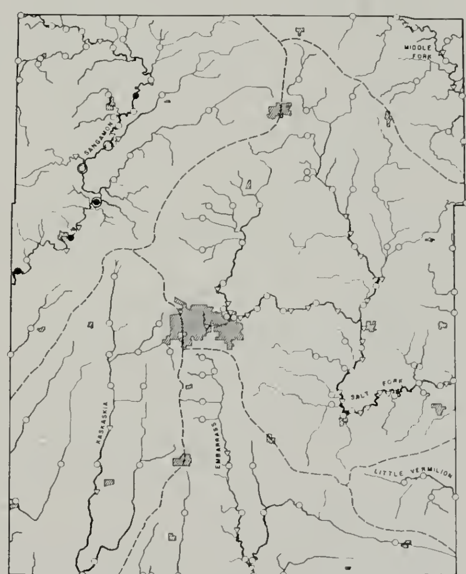

Fig. 70.—*Aplodinotus grunniens.*

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The scientific names of fishes indexed below include currently valid names, variant spellings, and synonymic names and combinations. Generic names, when they stand alone in the text, have not been indexed. Thus, *Carpiodes* spp. is not included in the index, but a text reference to any one of the species of *Carpiodes* is included. For convenience in indexing, specific and subspecific names are given equal rank. Thus, the subspecies *Notropis spilopterus hypsisomatus* is indexed as *Notropis hypsisomatus* and *hypsisomatus, Notropis,* and the subspecies *N. s. spilopterus* as *Notropis spilopterus* and *spilopterus, Notropis.* The common names used are those recommended by the Committee on Names of Fishes, American Fisheries Society. Common names used in a generic sense in the text (basses, sunfishes, catfish) have not been indexed. Common names for species have been indexed; common names for subspecies have not been indexed, as subspecies do not have officially recommended common names. Scientific names other than those of fish have not been inverted; for example, *Rorippa islandica* is listed but not *islandica, Rorippa.*

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