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The Fishes of Champaign County, Illinois,

During a Century of Alterations of a Prairie Ecosystem

R. Weldon Larimore and Peter B. Bayley

Illinois Natural History Survey Bulletin
Volume 35, Article 2
October 1996

Illinois Natural History Survey, Lorin I. Nevling, Chief
A Division of the Illinois Department of Natural Resources

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The Fishes of Champaign County, Illinois,
During a Century of Alterations of a Prairie Ecosystem

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Dedicated to

Lewis L. Osborne

friend, colleague, and visionary scientist who died suddenly soon after guiding to completion the project report upon which this Bulletin is based. He was directly responsible for the land-use and habitat analyses.

Contents

Acknowledgments

Many individuals contributed to the completion of this project, from its inception to the production of the final report that was prepared by Lewis Osborne, Peter Bayley, David Dowling, R. Weldon Larimore, Carolyn Nixon, James Peterson, Diane Szafoni, and Dana Dowling. This project report was submitted to the Illinois Department of Conservation for Research Project F-76-R, conducted with funding from the Federal Aid in Sport Fish Restoration Act. For the bulletin presented here, we retained from the project report the land-use and habitat analysis for which we are deeply indebted to the late Lewis L. Osborne. Thanks are extended to David Dowling and James Peterson for leading a well-disciplined field sampling team that provided the core of recent fish information presented here; Stephen Sobaski for computer consultation; Michael Morris and Lawrence Page for taxonomic assistance; Diane Szafoni, Carolyn Nixon, and Katherine Hunter for preparation of distribution maps; Katherine Darr and Deanne Krumwiede for typing the final manuscript; Charles Warwick and Thomas Rice for editing; James Smith and Phillip Fiscella for angling observations; David Philipp and Lawrence Page for reviewing the manuscript; two anonymous reviewers; and the many colleagues who participated in some portion of data collection during this study.

We acknowledge the use of several figures and descriptive text from the previous INHS Bulletin, Volume 28, Article 2, 1963, by Larimore and Smith.

Introduction

Streams and their aquatic communities are directly and indirectly influenced by the past and present activities of humans. In Champaign County, marshes and tallgrass prairie have been converted to farmland, cities, and highways. With these changes, former natural areas have become the dumping ground of domestic and agricultural wastes, with farmland being subjected to intense fertilizer and pesticide applications. Such practices can be expected to have significant influences on aquatic communities. Historical information on the fish communities inhabiting the streams of Champaign County (Forbes and Richardson 1908; Thompson and Hunt 1930; and Larimore and Smith 1963) in conjunction with data collected in the present study provide a unique opportunity to relate a century of biological observations to dramatic changes in land use. The importance of such a study is not restricted to its geographic location, nor to a unique assemblage of fishes, but rather to long-term patterns in fish community composition and structure in a midwestern, agricultural setting. Understanding the long-term implications of such changing land-use practices on stream fish assemblages is critical to sound environmental management and planning.

DESCRIPTION OF THE COUNTY

Champaign County occupies 1,038 square miles (2,688 km^2 or 664,320 acres) of flat to slightly rolling land in east-central Illinois (Figure 1). 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 additional stream systems originate a short distance north of the county.

In the past 150 years much of Champaign County has been converted from marshland to well-drained, fertile, and intensively cultivated farmland. Its streams have been modified by dredging, tiling, silting, and other influences that accompany agricultural practices. The human population has rapidly increased during 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.

The Grand Prairie

The county has been glaciated at least twice, but the effects of the more recent Wisconsinan stage (about 18,000 to 11,000 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, form boundaries between drainage systems. The entire county is overlaid with a mantle of Wisconsinan 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.

The retreating Wisconsinan ice sheet left behind a flat basin of glacial till covered with loess and interrupted only by moraines and low-gradient streams. Mesic forests at first dominated the landscape (King 1981). Then, about 8,000 years ago during a drying and warming trend, prairie replaced the forests. Indians and early Europeans saw this Grand Prairie as a threatening marsh, with swales, indistinct streams, and expanses of onerous tall grass. Bands of trees along the larger streams and moraines provided wood and dry ground for hunters and travelers who usually stayed to hunt or rest and move on beyond the uninviting tall grass, mosquitoes, and deer flies. Champaign County lies near the center of this Grand Prairie (Figure 1).

Soils of the Grand Prairie reflect the soil parent material, drainage patterns, and the vegetational history of the area. Dark upland prairie soils make up about 92% of the area; yellow-gray silt loams, the upland timber soils, make up about 5%; bottomland or terrace soils constitute the remainder (Hopkins et al. 1918). A group of silty loess prairie soils covers about 40% of Champaign County, which, when properly managed, are the most productive in the county. A second group of prairie soils, consisting of silty outwash soils with greater subsurface flow and higher permeability, covers about 26% of the county. This group of soils, also very productive, 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% 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% of the county. This group is somewhat less productive than the other prairie soils. The remaining group, consisting of nonprairie soils, is generally associated with the river valleys and constitutes the least productive soils of the county.

Weather

Champaign County has a temperate continental-type climate. Temperature extremes range from below 0°F (-18°C) to over 100°F (38°C), with an annual mean of 52°F (11°C) (Changnon 1959). The county receives an average of about 36 inches of precipitation per year.

Figure 1

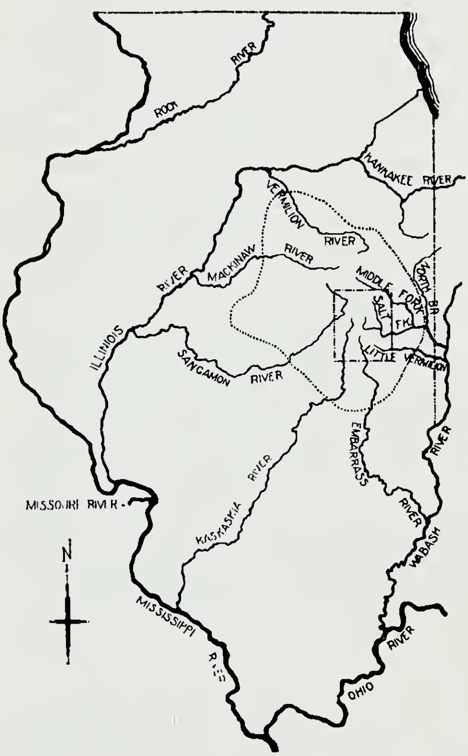


Figure 1. Location of Champaign County and its streams in relation to the state and major drainage systems. The dotted line indicates the boundary of a particularly fertile area, the Grand Prairie, at one time mostly prairie marsh. (From Larimore and Smith 1963).

Stream Drainages and Courses

Six rivers have headwater areas in the county, four of which (Salt Fork, Embarras, Kaskaskia, and Little Vermilion) originate within the county (Figure 1). 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 areas (in square miles) of each of these rivers within the county are as follows: Sangamon = 277, Salt Fork = 346, Middle Fork = 69, Embarras = 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 outside the county are shown in Figure 1. The total drainage areas (in square miles) of the main courses where they leave Champaign County are as follows: Sangamon = 388, Salt Fork = 307, Middle Fork = 241, Embarras = 106, Kaskaskia = 98, and Little Vermilion = 28. These figures include upper reaches of those rivers that rise outside the county.

Annual average discharge records (U.S. Geological Survey Annual Reports) for two gaging stations near the border of the county and for three stations well within the county were available at the time of the Larimore and Smith survey. The size of drainage basin streams at these stations was recorded and indicates the amount of water drained from the different watersheds. The records also showed that the annual average discharge of water per acre in the period ending in 1957 was 0.7 cubic feet per second (cfs) per acre of drainage for the Sangamon, Salt Fork, and Saline Branch; 0.6 cfs per acre for the Kaskaskia; and 1.0 cfs per acre for Boneyard Creek. The lowest discharge per acre was for the Kaskaskia drainage, which at that time was entirely farmland, and the highest discharge was for the Boneyard drainage, which was almost entirely urban, lying within Champaign-Urbana.

Records taken by the U.S. Geological Survey on the Sangamon River, just outside the county near Monticello, were of special interest because they covered a period including the past three surveys, and reflected runoff in about one quarter of the county. In a statewide analysis of trends from 1915 to 1991, Knapp

(1994) noted that below-normal flows were apparent in the 1930s and 1950s, and above-normal flows in the 1970s and early 1980s. However, he could not detect significant long-term trends (P=0.05) in average, 7-day high, or 7-day low flows at stations in central or southern Illinois, including data analyzed separately from the Sangamon gauge.

Discharge during previous years may have affected fish species. However, studies from the region have shown that most fishes return to drought-affected reaches by the following year (Larimore et al. 1959; Bayley and Osborne 1993). Low-water conditions during sampling will increase the efficiency of capture (Bayley and Dowling 1990, 1993), while very low water in the spring may reduce the number of species moving into lower-order streams. The ranks (1 through 12) of annual 7-day low-flow discharges of sampled years during 12-year periods culminating in each sampled year were 7 (1928), 7 (1929), 5 (1959), 7 (1960), 4 (1987), and 1 (1988). Similar ranks were encountered for annual mean flows. Therefore, Thompson and Hunt sampled during nearly average flows compared with previous 12-year periods, Larimore and Smith below- or near-average flows, and Larimore and Bayley below-average flows. These discharges from all sampled years were between 25% and 75% quartiles except for 1988, which was a drought year when flow was interrupted in second order streams (Bayley and Osborne 1993). Most fish samples from the 1987/88 survey were taken in 1987 (72% of total), and analyses that follow either account for gear efficiency, include only 1987 samples, or assess changes in frequency of occurrence of species very conservatively.

General Stream Habitats

Most Champaign County streams now originate at drain tiles, on the slopes of moraines, or in flat, marshy areas (Figures 2 and 3). They usually flow through straight, man-made ditches in farmland and move into less disturbed channels as they become larger and their valleys widen. The relatively flat topography, lack of rock outcrops, similarity of soil materials, and intensive land-use practices produce an unusual amount of uniformity in the stream environment, as will be discussed later.

The stream gradient is generally low, usually between 3 and 4 feet of fall per mile (0.06-0.08%). Only on the slopes of moraines and in a few short stretches does it exceed 6 feet per mile (0.1%). The flow is generally moderate to sluggish during normal water stages. Riffles are gentle and pools are rather shallow. There are long runs of uniform depth and flow. Water levels fluctuate rapidly and drastically. Flooding occurs with some regularity, particularly during the spring and early summer. During flood stages the water levels may rise 10 to 15 feet and streams temporarily become torrents that erode away stream banks. Within the county, the Sangamon, Salt Fork, and Middle Fork rivers, and to a lesser degree the Embarras River, have narrow floodplains, often restricted by artificial levees; these floodplains may be completely inundated during floods. Dry periods occur nearly every year, usually during August and September when flow may decrease drastically or even cease, especially in the small headwater tributaries.

Water temperatures in shallow, unshaded reaches may exceed 95°F (35°C) during summer and freeze in winter. There are no large springs to moderate water temperatures. The lack of shading bank vegetation along shallow water areas allows extreme daily temperature fluctuations, which in summer cause changes as great as 20°F (11°C) between the cool morning hours and the hot mid-afternoon. In winter, temperatures may drop sufficiently to freeze water to the stream bottom in shallow areas. Because fishes generally concentrate in deep pools in winter, they are seldom trapped in the ice.

The distribution of bottom materials is directly related to the velocity of the water. Through selective sorting of the basic materials, coarse particles of rubble and gravel accumulate in riffle areas, sand accumulates in areas of moderate current, and the fine particles of silt and clay drop out only in the quiet waters of deep pools.

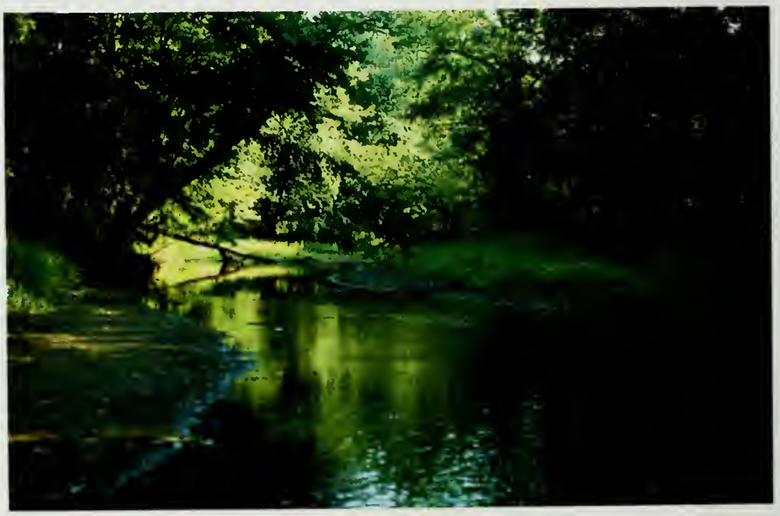
Turbidity is generally high during the summer in larger streams, becoming low only in the fall when leachates from tree leaves settle the suspended particles and cold water reduces fish activity so they do not roil silt on the bottom. The streams are said to be "winter clear." The chemistry of stream water is related to the mineral composition of the watershed and has been strongly influenced by domestic and industrial pollution (see pages 96-104).

(Continued on page 58)

Figure 2

Before settlement, swales were the headwaters of the diffuse prairie streams.

As the streams left the flat prairie, they gained a discrete channel with some woody vegetation and glacial boulders.



The larger streams had heavy woody vegetation.

Figure 3

Agricultural development drained the prairie swales and replaced sedges and grasses with corn and some wheat.

The prairie streams were dredged, providing uniform ditches.

The larger streams still in the flat prairie lands were also dredged.

Much of the natural aquatic vegetation in Champaign County streams may have been eliminated early in the 20th century through dredging (Figure 4), pollution, and other human-induced alterations. The remaining submerged vegetation is limited in distribution by the generally high turbidity in the streams. The field notes of Thompson and Hunt and of Larimore and Smith indicate that aquatic vegetation was more extensive in 1928 than in 1959. Most plants listed by those surveys are not true aquatics but are characteristically associated with the banks and mud flats along streams. A few true aquatics were listed by Larimore and Smith (1963). *Potamogeton foliosus* was quite common in part of Lone Tree Creek. *Chara* sp. was taken near a seepage spot on a tributary of the Spoon River near Flatville. *Elodea canadensis* occurred in large patches in the polluted Saline Branch between Urbana and St. Joseph but now is rare. *Justicia americana* was abundant in the riffles and along the shores of many streams, especially in the Middle Fork and lower Salt Fork. It declined in many reaches of the lower Salt Fork in the 1960s, but is now abundant again (Figure 3). As part of the recent fish survey, Tazik et al. (1991) recorded the aquatic plants present at 112 of our stations scattered through all six drainage basins in the county. They collected 36 species of vascular plants at 38 stations. Although the number of species listed by each survey has increased, many species have been absent in successive surveys. Tazik et al. (1991) concluded that the present species indicate a continued degradation of the streams, possibly because of the increased use of herbicides and periodic channel maintenance.

The present riparian vegetation includes grasses, sedges, ragweeds, milkweeds, docks, and several composites along the small streams as they pass through flat and open farmlands. In some of the reaches of these streams, willows and scrubby growths of a few other deciduous trees overhang the water. Tall deciduous trees line the banks of most of the large streams (Figures 2, 3, and 5). Especially common are silver maple, cottonwood, sycamore, and willows. The American elm, once dominant along streams, died off during the 1960s from Dutch elm disease. In open areas, where sunshine reached the water, scattered patches of buttonbush, rose mallow, water willow, and a few other semi-aquatic plants grew.

DEVELOPMENT OF AGRICULTURE

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

The farming of the first settlers in this county was largely restricted to raising cattle and small crops on high areas and along the stream courses where drainage was naturally good (Figure 5). Lands that were dry enough for cultivation were turned by oxen. In 1836, John Deere invented the steel self-scouring plow that permitted plowing the moist meadows. Railroads entered the area in the 1850s, permitting movement of farm products to markets in Chicago.

By 1900, farms averaged between 80 and 100 acres in size, but with the development of large farm machinery, such as heavy tractors, combines, seeders, and corn pickers, many farms were merged to form larger ones. By 1960, the average Champaign County farm was about 200 acres. These trends were associated with less diversification among farm crops, with corn and soybeans becoming the two leading crops. Fewer cattle are being raised.

During the 1940s, the widespread use of commercial fertilizers brought about a general increase in average yield. Hybrid plants and improved varieties added to yields. More recently, ammonium as a fertilizer and herbicides further increased production. Presently, virtually every acre in corn and soybeans receives herbicides, and the practice of minimum tillage has further increased the use of selective herbicides.

At the time of settlement, 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 conserva-

(Continued on page 60)

Figure 4

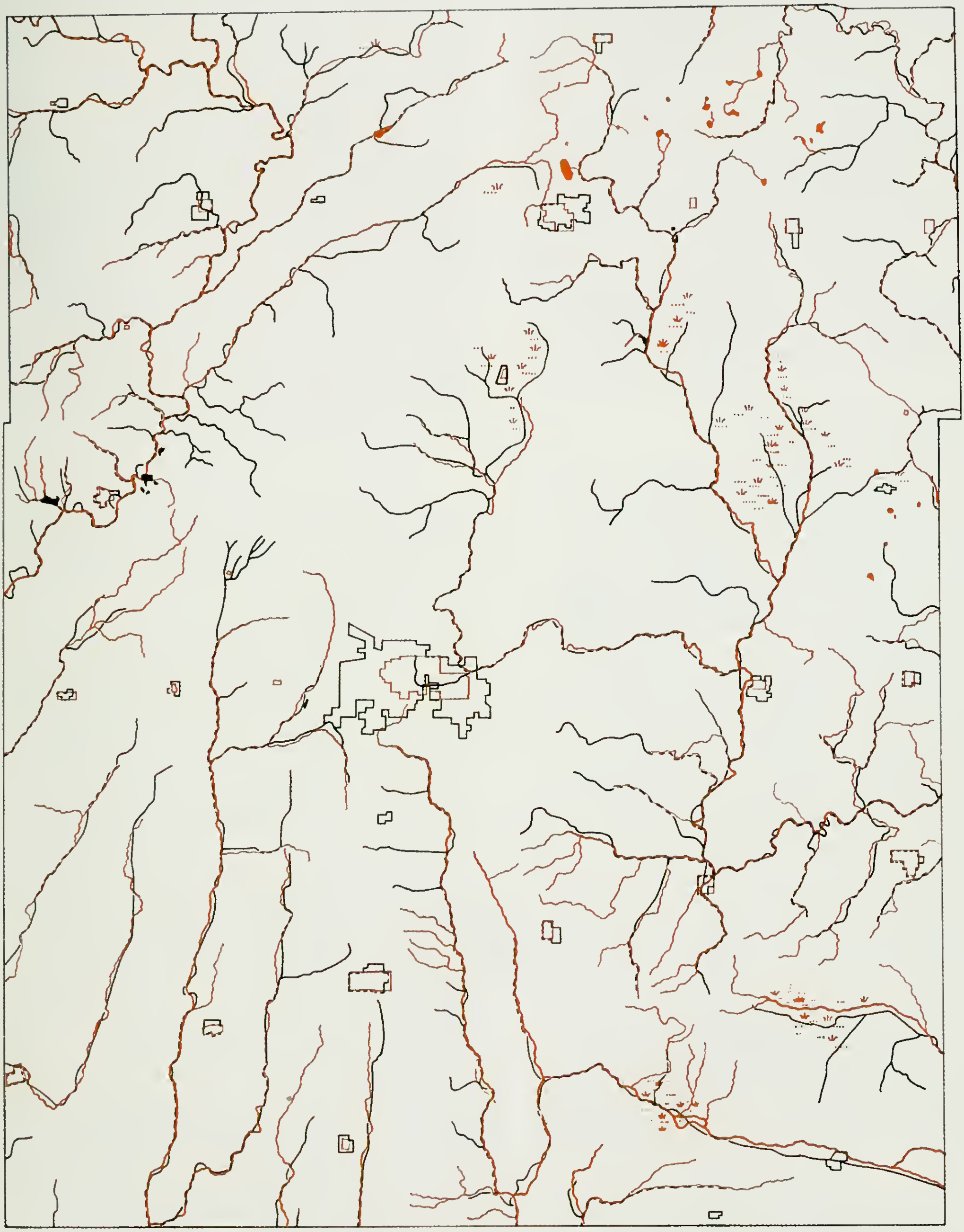


Figure 4. Map showing distribution of towns and water areas in Champaign County in the 1870s (in red) and the 1950s (in black) (from Larimore and Smith 1963).

tion practices had adverse effects upon 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 were not fully appreciated by many Champaign County farmers up to 1960. Few grainfields were farmed on the contour, strip cropping was rare, and grass waterways were maintained in relatively few of the cultivated fields. Farm animals were permitted to graze stream banks and thereby contribute to serious erosion and siltation. During the following three decades, these conservation needs have been recognized and better strategies put into practice. Reduced cattle raising has largely eliminated grazing damage. The few remaining large feedlots are required by law to have oxidation ponds to prevent direct runoff into streams.

Draining and Dredging

Because of the original marshy nature of Champaign County, much draining, dredging, and straightening of waterways has been necessary to prepare the land for agriculture. Farmers started ditching their fields in the 1850s. In 1870, the first drainage district in the county was established in the Saline Branch of the Salt Fork basin (Hay and Stall 1974). 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 and Richardson made the first extensive fish collections in the area, 36% of the county's 664,320 acres had drainage alterations. The number of acres in drainage districts almost doubled between 1900 and 1910, with 190,205 additional acres (30% of the county) receiving drainage improvements. In the decades since 1910, the amount of new land drained declined. The acreage of land placed in drainage districts in the three decades between 1930 and 1960 (the second and third surveys) amounted to only 8% of the area of the county.

When Thompson and Hunt made their collections in 1928, 74% of the county was in drainage districts. By 1959, 82% of the county (520,100 acres) had received drainage improvements. Of the 18% of the county remaining, a considerable proportion has adequate natural drainage or is in nonagricultural use. Present drainage work consists mostly of maintenance and enhancement 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 (Figures 2 and 3). Channelization of natural streams resulted in straightening them, the erection of high earthen banks along the sides, production of greater uniformity of the stream environments, and drastic alterations of local stream habitats (Figures 3 and 4).

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 reduced the water storage capacity of the watershed and contributed to higher flood and lower drought levels in the streams. These practices have lowered the water table and affected the permanency of many small streams.

Two stations sampled by Thompson and Hunt, 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, no longer existed by 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 and Hunt were completely dry in the summers of 1959 and 1987, probably due to the dry summer rather than to recent human-induced modifications or to long-term natural changes.

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; and in 1987, 172,700. The trend has been toward urbanization; in 1900, 31.1% of the population lived in urban areas and, in 1960, 75.6%. Although there are 26 cities and villages in the county, only Champaign-Urbana, Rantoul, and a few others have increased in population. Populations in the remaining villages in the county have remained stable or have even declined.

A considerable acreage of farmland has been usurped by urban and suburban development (Figures 4 and 5). The total number of acres in cultivation remained roughly the same between 1900 and 1928. Since 1928, cleared land, particularly that bordering cities and villages, has been converted to nonagricultural uses. Many areas that were once farmed are now covered by schools, grain storage units, and industrial, commercial, and housing developments; other large land areas are occupied by Chanute Air Force Base (recently decommissioned) and the campus of the University of Illinois. During the decade before the recent survey, 300 acres of farmland were converted annually to nonagricultural uses, mostly due to the spread of Champaign-Urbana. The vast network of roads, including several major highways that transect the county, occupies a large and ever-increasing area. This trend of agricultural land being lost to urbanization is presented in detail in the section "Land Use and Stream Habitats" (pages 77-91).

A highly developed road system has made Champaign County ideally suited for the study reported here because most roads are laid out in an orderly and regular manner, 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, but away from road bridges that influence fish habitats.

Figure 5

Figure 5. Comparison between presettlement forests and present-day forests in Champaign County. Remaining open areas (unshaded) are dominated by agriculture.

FISHES COLLECTED DURING THE FOUR SURVEYS

The major objectives of this study were to analyze changes in the fish species of Champaign County during the past 90 years and to identify components of the fish assemblages that have changed significantly, building on the previous surveys conducted at close to 30-year intervals by Forbes and Richardson (1908), Thompson and Hunt (1930), and Larimore and Smith (1963). In the present survey, we replicated as many of the previous sampling sites as possible, and employed the same sampling methods used by Larimore and Smith.

Methods

Sampling methods are a major consideration when comparing populations, communities, or even the presence or absence of a species. The first two surveys used the minnow seine without block nets; the two following surveys mostly used the electric seine with block nets.

Details of Forbes and Richardson's survey, which was part of a larger statewide survey conducted mostly in 1899, are understandably lacking because of the predominantly taxonomic nature of that study. Although Larimore and Smith identified 48 stations in Champaign County visited by Forbes and Richardson, we found clear species and location information for only 46 samples from the original data cards for that first survey. Although these samples were taken from 1885 through 1901, most of them were collected in 1899 and 1901. Because the data cards did not always show clearly the quantities of fish caught for every species noted, we used Forbes and Richardson's data only for presence/absence analysis.

Thompson and Hunt completed a more comprehensive survey during 1928-29, revisiting 46 of the Forbes and Richardson sites. They collected most of their samples (126 sites) using a 10 ft x 4 ft seine net with a one-sixth-inch square mesh. All but 1 of these 126 stations were replicated by the next two surveys. Thompson and Hunt collected six additional samples using a 75 ft x 6 ft-deep seine with a 1-inch square mesh.

The Larimore and Smith survey in 1959-1960 used the more efficient 30-foot electric seine between block nets (Larimore 1961; Bayley et al. 1989) for quantitative samples and a net seine for qualitative samples. They took a total of 191 samples, of which 40 were from stations revisited during their survey where qualitative net seine samples were taken. Of the 151 nonrepeated (i.e., sites visited once only) samples, 82 were samples using the electric seine between block nets, and 69 were net seine samples. Larimore and Smith's "cruising" samples, which were seine net hauls taken outside the block nets to pick up additional species in other nearby habitats, were not included in the following analysis but are recognized in Tables 1 and 2, the Annotated List of Fishes (Appendix 1), and the Species Distribution Maps for All Four Surveys (Appendix 2).

The present study replicated the sampling methods of Larimore and Smith. Most of their quantitative methods using the electric seine were described in sufficient detail to permit unbiased estimates of abundance, biomass, and species richness using gear efficiencies derived by Bayley and Dowling (1990, 1993). This resulted in 75 of Larimore and Smith's samples being replicated and corrected for efficiency. In addition, we sampled 66 of Larimore and Smith's stations. Overall, 141 of 151 stations sampled by Larimore and Smith were replicated by the present study. Of these 141 samples, 101 (72%) were sampled in 1987, practically all using the electric seine. Of the remaining 40 samples taken in 1988, 85% were seine net samples, replicating Larimore and Smith qualitative samples. Nine of Larimore and Smith's stations on first-order streams were dry and one station was not accessible during the present study.

Analyses had to account for the different qualities of sampling among surveys. When comparing all four surveys, we compared total species numbers and presence/absence pooled across samples within the survey. When comparing the past three surveys, proportions of fish numbers of each species were also compared. Further details of samples used for each analysis are given in the following section, "Analysis and Discussion."

Except for larger fishes that were processed in the field, fish samples from this study were preserved in 10% formalin to be subsequently sorted, identified, and measured and weighed using an electronic caliper and balance (Bayley and Illyes 1988) in the laboratory.

This allowed large quantities of collection data to be processed and transferred to computer files. Preserved subsamples of fishes from each sample were transferred to 70% ethanol and added to the Illinois Natural History Survey Fish Collection.

Current taxonomic knowledge (see Appendix 1, "Annotated List of Fishes") influenced the amount of information to be gained from each survey and, hence, from comparisons among them. Table 1 lists the scientific and common names currently in use. Identifications that could have been confused in earlier work are designated as "species pairs" in part of the analysis. For example, rainbow and orangethroat darters were not distinguished at the time of the first two surveys. Several such pairs were likely dominated by one species, based on biogeographical information from the past 40-50 years and specimens still extant in the INHS Fish Collection. For example, the redfin shiner is much more common than the ribbon shiner. The ribbon shiner may have been present during the first two surveys in the county, but this has not been verified. Species pairs were treated separately when both species were known and identified, as occurred in the two most recent surveys. Development of taxonomic information for most species is given in Appendix 1.

Presence/absence

The lowest level comparison among all four surveys is provided by a presence/absence list of species (Table 1). Using information from all samples taken, including some samples replicated at the same site in the same survey, 92 species are indicated, but not all samples have voucher specimens for verification.

Larimore and Smith collected nine species not previously recorded from Champaign County (Table 2). Three of these were new invaders: the ribbon shiner moving in from the south, and the red shiner and freckled madtom from the west. Three species were occasional seasonal visitors from larger downstream waters: the longnose gar, river carpsucker, and yellow bass. The redear sunfish was from locally stocked populations, and mosquitofish and goldfish were probably from aquarium releases.

In the recent survey, we took four species new for the county. The northern pike, white bass, and walleye were probably from stocked populations. The latter two and the shortnose gar were invaders from downstream.

In spite of losing species from one survey to the next, the total number of species remained about the same during the past three surveys (Table 2). As the numbers of previously unrecorded species decreased, the numbers of previously recorded species not taken in each succeeding survey increased. On the other hand, the percentage of previously recorded species declined from one survey to the next. Between the second and third surveys, 11% of previously recorded species were lost; between the third and fourth surveys, 3% were lost. Those percentages seem to contradict the following percentages because they include missing species retaken in following surveys. Eighteen species that had been recorded in the previous three surveys were not taken in the recent survey. Of these 18 species, 2 species (3% of recorded species) disappeared before the second survey and were not taken later, 9 (11%) more before the third survey, and 7 (8%) additional species before the fourth survey. These 18 species included 6 now listed as state endangered (E) species (Herkert 1992). Disappearing between the first and second surveys and not taken later were the silver chub (E) and blacknose shiner (E). Disappearing between the second and third surveys and not taken later were the goldeye, bigeye chub (E), bigeye shiner (E), pallid shiner (E), pugnose minnow, bullhead minnow, slender madtom, slough darter, and bluntnose darter. Between the third and fourth surveys the following fishes disappeared and were not taken: Mississippi silvery minnow, mimic darter, warmouth, mosquitofish, yellow bass, eastern sand darter (E), and banded darter. Based on the four county surveys, 16 of those 18 species had never been common in Champaign County during the past century. The bigeye chub has declined or disappeared in many parts of its range, as has the bigeye shiner. Both species are listed as endangered in Illinois but still occur in neighboring Vermilion County (Burr et al. 1996). Goldeye, black buffalo, and yellow bass are only occasional invaders into the county from the larger downstream waters and will likely occur again. The Mississippi silvery minnow prefers streams larger than those of this county.

(Continued on page 68)

Table 1. Fishes recorded from Champaign County during each of the four surveys, along with footnoted miscellaneous records. Species recorded= +; species not distinguished by collector but probably occurred= ?; undistinguished by collector but preserved collection contained species = ?+; no record = 0. Nomenclature follows that of Robins et al. (1991) or Page and Burr (1991).

Family Species	Forbes & Richardson 1899-1901	Thompson & Hunt 1928-1929	Larimore & Smith 1959-1960	Larimore & Bayley 1987-1988	Misc. records
Lepisosteidae					
Lepisosteus osseus Longnose gar	0	0	+	+	
Lepisosteus platostomus Shortnose gar	0	0	0	+	
Hiodontidae					
Hiodon alosoides Goldeye	0	+	0	0	1
Clupeidae					
Dorosoma cepedianum Gizzard shad	+	+	+	+	
Cyprinidae					
Campostoma anomalum Central stoneroller	+	+	+	+	
Carassius auratus Goldfish	0	0	+	+	2
Cyprinella lutrensis Red shiner	0	0	+	+	
Cyprinella spiloptera Spotfin shiner	?	?+	+	+	3
Cyprinella whipplei Steelcolor shiner	?	?+	+	+	3
Cyprinus carpio Common carp	+	+	+	+	
Ericymba buccata Silverjaw minnow	+	+	+	+	
Hybognathus nuchalis Mississippi silvery minnow	+	+	+	0	
Hybopsis amblops Bigeye chub	+	+	0	0	4
Hybopsis amnis Pallid shiner	0	+	0	0	5
Luxilus chrysocephalus Striped shiner	+	+	+	+	
Lythrurus fumeus Ribbon shiner	0	0	+	+	6
Lythrurus umbratilis Redfin shiner	+	+	+	+	
Macrhybopsis storeriana Silver chub	+	0	0	0	
Nocomis biguttatus Hornyhead chub	+	+	+	+	
Notemigonus crysoleucas Golden shiner	+	+	+	+	
Notropis atherinoides Emerald shiner	+	+	+	+	
Notropis boops Bigeye shiner	+	+	0	0	4
Notropis dorsalis Bigmouth shiner	+	+	+	+	
Notropis heterolepis Blacknose shiner	+	0	0	0	5
Notropis rubellus Rosyface shiner	0	+	+	+	

(*Table 1 continued*)

Family Species	Forbes & Richardson 1899-1901	Thompson & Hunt 1928-1929	Larimore & Smith 1959-1960	Larimore & Bayley 1987-1988	Misc. records
Notropis stramineus Sand shiner	?	?+	+	+	7
Notropis volucellus Mimic shiner	?	?+	+	0	
Opsopoeodus emiliae Pugnose minnow	0	+	0	0	
Phenacobius mirabilis Suckermouth minnow	+	+	+	+	
Pimephales notatus Bluntnose minnow	+	+	+	+	
Pimephales promelas Fathead minnow	+	+	+	+	
Pimephales vigilax Bullhead minnow	+	+	0	0	
Semotilus atromaculatus Creek chub	+	+	+	+	
Catostomidae					
Carpiodes carpio River carpsucker	0	0	+	+	
Carpoides cyprinus Quillback	+	+	+	+	
Carpoides velifer Highfin carpsucker	+	+	+	+	
Catostomus commersoni White sucker	+	+	+	+	
Erimyzon oblongus Creek chubsucker	+	+	+	+	
Hypentelium nigricans Northern hogsucker	+	+	+	+	
Ictiobus bubalus Smallmouth buffalo	+	0	0	+	
Ictiobus cyprinellus Bigmouth buffalo	0	+	0	+	
Ictiobus niger Black buffalo	0	+	0	+	
Minytrema melanops Spotted sucker	+	+	+	+	
Moxostoma anisurum Silver redhorse	0	+	+	+	
Moxostoma duquesnei Black redhorse	?+	?	0	+	8
Moxostoma erythrurum Golden redhorse	?+	?+	+	+	
Moxostoma macrolepidotum Shorthead redhorse	+	+	+	+	
Ictaluridae					
Ameiurus melas Black bullhead	+	+	+	+	
Ameiurus natalis Yellow bullhead	+	+	+	+	
Ictalurus punctatus Channel catfish	+	+	+	+	
Noturus exilis Slender madtom	0	+	0	0	
Noturus flavus Stonecat	+	+	+	+	
Noturus gyrinus Tadpole madtom	+	+	+	+	

(*Table 1 continued*)

Family Species	Forbes & Richardson 1899-1901	Thompson & Hunt 1928-1929	Larimore & Smith 1959-1960	Larimore & Bayley 1987-1988	Misc. records
Noturus miurus Brindled madtom	+	+	+	+	
Noturus nocturnus Freckled madtom	0	0	+	+	
Pylodictis olivaris Flathead catfish	0	+	+	+	
Esocidae					
Esox americanus Grass pickerel	+	+	+	+	
Esox lucius Northern pike	0	0	0	+	9
Aphredoderidae					
Aphredoderus sayanus Pirate perch	+	+	+	+	
Fundulidae					
Fundulus notatus Blackstripe topminnow	+	+	+	+	
Poeciliidae					
Gambusia affinis Western mosquitofish	0	0	+	0	
Atherinidae					
Labidesthes sicculus Brook silverside	+	+	+	+	
Moronidae					
Morone chrysops White bass	0	0	0	+	10
Morone mississippiensis Yellow bass	0	0	+	0	10
Centrarchidae					
Ambloplites rupestris Rock bass	0	+	+	+	
Lepomis cyanellus Green sunfish	+	+	+	+	
Lepomis gulosus Warmouth	+	+	+	0	
Lepomis humilis Orangespotted sunfish	+	+	+	+	
Lepomis macrochirus Bluegill	+	+	+	+	
Lepomis megalotis Longear sunfish	+	+	+	+	
Lepomis microlophus Redear sunfish	0	0	+	+	11
Micropterus dolomieu Smallmouth bass	+	+	+	+	
Micropterus punctulatus Spotted bass	?	?	+	+	12
Micropterus salmoides Largemouth bass	?+	?+	+	+	
Pomoxis annularis White crappie	+	+	+	+	
Pomoxis nigromaculatus Black crappie	+	+	+	+	
Percidae					
Ammocrypta pellucida Eastern sand darter	0	+	+	0	5
Etheostoma asprigene Mud darter	+	0	+	+	
Etheostoma blennioides Greenside darter	+	0	+	+	

(*Table 1 continued*)

Family Species	Forbes & Richardson 1899-1901	Thompson & Hunt 1928-1929	Larimore & Smith 1959-1960	Larimore & Bayley 1987-1988	Misc. records
Etheostoma caeruleum Rainbow darter	?	?+	+	+	
Etheostoma chlorosomum Bluntnose darter	+	+	0	0	
Etheostoma flabellare Fantail darter	+	+	+	+	
Etheostoma gracile Slough darter	0	+	0	0	
Etheostoma nigrum Johnny darter	+	+	+	+	
Etheostoma spectabile Orangethroat darter	?	?+	+	+	13
Etheostoma zonale Banded darter	0	+	+	0	
Percina caprodes Logperch	+	+	+	+	
Percina maculata Blackside darter	+	+	+	+	
Percina phoxocephala Slenderhead darter	+	+	+	+	
Percina sciera Dusky darter	+	0	+	+	
Stizostedion vitreum Walleye	0	0	0	+	10
Sciaenidae					
Aplodinotus grunniens Freshwater drum	0	+	+	+	

1) Had been misidentified as *Hiodon tergisus* by Thompson & Hunt. Specimen extant.
2) Probably released aquarium fish. No evidence of established population.
3) Not distinguished by Forbes & Richardson but, because of present widespread abundance, the species was probably included in their composite *Notropis whipplii.*
4) Listed as an endangered species in Illinois. Still occurs in Vermilion County east of Champaign County.
5) Listed as an endangered species in Illinois.
6) Although widespread in southeastern Illinois, the ribbon shiner was not found in extant Champaign County collections of Forbes & Richardson nor Thompson & Hunt, who may not have recognized the species. Still rare and only in Embarras River drainage of Champaign County.
7) Included in the composite *Notropis blennius* of Forbes & Richardson and Thompson & Hunt. No collections of Forbes & Richardson extant but species no doubt occurred, considering its distribution in the following surveys.
8) Taken by T. Large, a colleague of Forbes, in 1899 from Salt Fork. Specimen extant. None included in Forbes & Richardson or Thompson & Hunt collections still extant. Larimore & Smith collected it from Salt Fork outside the county.
9) Early angling information suggests that this pike was often taken around the marshes of east-central Illinois. Recently stocked in county lakes and taken in associated streams.
10) Seasonal invader from downstream reservoir.
11) Escaped from stocked lakes and taken several times in county streams.
12) Not distinguished by Forbes & Richardson nor Thompson & Hunt, but, because of its present distribution, the species was included in the composite *Micropterus salmoides* in the first two surveys.
13) Not distinguished by Forbes & Richardson, but, based on their present abundance, both species were in the composite of *Etheostorma caeruleum.*

Table 2. Occurrence categories of fishes taken and recorded in Champaign County during each of the four surveys. Indigenous species are those native to the county. Introduced species are those that have been stocked in the county or in downstream reservoirs, dispersed into the county, and have been taken more than once in county streams.

Occurrence Category	Forbes & Richardson	Thompson & Hunt	Larimore & Smith	Larimore & Bayley
Indigenous species	64	72	69	68
Introduced species	1	1	4	6
Previously unrecorded species	0	14	9	4
Previously recorded species not taken	0	6	15	18
Total number of species recorded	65	73	73	74
Total number of species recorded (cumulative)	65	79	88	92

Species Richness

The number of stations that was sampled more than once within surveys varied, which resulted in large differences between the total number of samples among surveys. This increased the probability that species would be encountered in surveys with more samples, such as that of Larimore and Smith. Moreover, species richness efficiency varied among sampling methods, averaging about 50% for net seines, which were used exclusively in the first two surveys, and 85% for electric seines (Bayley and Dowling 1990, 1993). Therefore, an unbiased comparison of species richness is the mean estimated species richness per sample for each survey (Figure 6). A significant drop in this corrected measure of biodiversity occurred between 1928 and 1959, a period during which water quality and land-use effects caused a rapid deterioration in stream habitats. A slight increase is suggested between the past two surveys (see also the following comparisons between 1959 and this study), but mean richness per sample is still considerably less than during the first two surveys.

Fish Assemblages

As in the foregoing species richness analysis, the total of 463 nonrepeated samples was used from the four surveys to assess differences in assemblage structure and trends in occurrence of individual species. Because of potential confounding of pairs of some species referred to earlier, 80 independent taxa (species and species pairs) resulted from the nonrepeated samples (Table 3). Similarity indices can be useful for deriving similar groups of communities or stations, but it is difficult to test for the significance of such indices. Here we used two-way tables of frequencies that were tested against the null hypothesis that frequencies were the average frequencies across all surveys. Two comparisons of assemblage differences were tested. First, the relative percentage occurrence of taxa among samples was compared across surveys. Second, the relative percentage occurrence of numbers of fish by taxa pooled across samples within surveys was compared across surveys. The second comparison could not include the first survey because Forbes and Richardson's data lacked records of numbers of fish for some taxa. Statistical validity of these tests depends on sufficient counts in cells, and some less frequently caught species are more likely to bias the results due to gear efficiency differences. Therefore, subsets of common taxa were selected as described below.

In the first comparison, a subset of 47 taxa (including five species pairs) that occurred in five or more samples from two or more surveys provided sufficient expected cell frequencies to test for differences in the distribution of percentage occurrences of taxa among surveys (Table 4). The test produced a chi-squared value at $p<0.00001$, indicating that the distribution of species among samples differed among the four surveys. A test using 15 more common species that occurred in at least 10 nonrepeated samples from each survey was also highly significant ($p<0.00001$). Similar highly significant results were obtained when the less extensive Forbes and Richardson data were excluded. The second comparison of relative numbers of fish by species indicated highly significant chi-squared values ($p<0.000001$) using the same subset of 47 taxa, and using the 15 most common taxa.

The following statistical tests identified the most influential taxa responsible for these assemblage changes. Multiple testing by species was performed in two stages. First, heterogeneity among surveys of the proportion of samples containing each species was tested using a chi-squared test of association. Rejection of the null hypothesis meant that there was some heterogeneity in the proportions in two or more surveys, but no order was implied. Failure to reject this hypothesis resulted in no further tests being made for those species (see last section in Table 4). Because this was a multiple testing procedure, Bonferroni probabilities were applied by multiplying the separate probabilities by the number of tests (here 47).

In the second stage, the remaining 27 species that indicated differences at $p=0.05$ were subjected to a time trend analysis. Because the surveys were conducted between similar time intervals, they were coded as times 1 through 4 (Forbes and Richardson through to the recent survey). A logistic-linear regression within the Generalized Linear Interactive Modeling procedure was used in which the response variable was the proportion of samples containing the species in each survey. The explanatory function is a linear function of time (a + bt, where a and b are constants). Assuming binomial error distribution, the change in deviance resulting from the inclusion of the linear time coefficient, b, is distributed as chi-squared, and serves as a test for a significant temporal trend. Temporal autocorrelation was not evident, which was not surprising considering the long time intervals between surveys. These tests were also multiple, so Bonferroni probabilities were applied. This is the most conservative approach, which we believe is appropriate because probabilities of encountering less common species with the net seine in the first two surveys will tend to be less than in the surveys dominated by the electric seine. Species with significant positive and negative trends are grouped in Table 4. We have collected the remaining species, which have significant differences among surveys but nonsignificant linear trends, into three groups that suggest more complex changes in time.

(Continued on page 73)

Figure 6

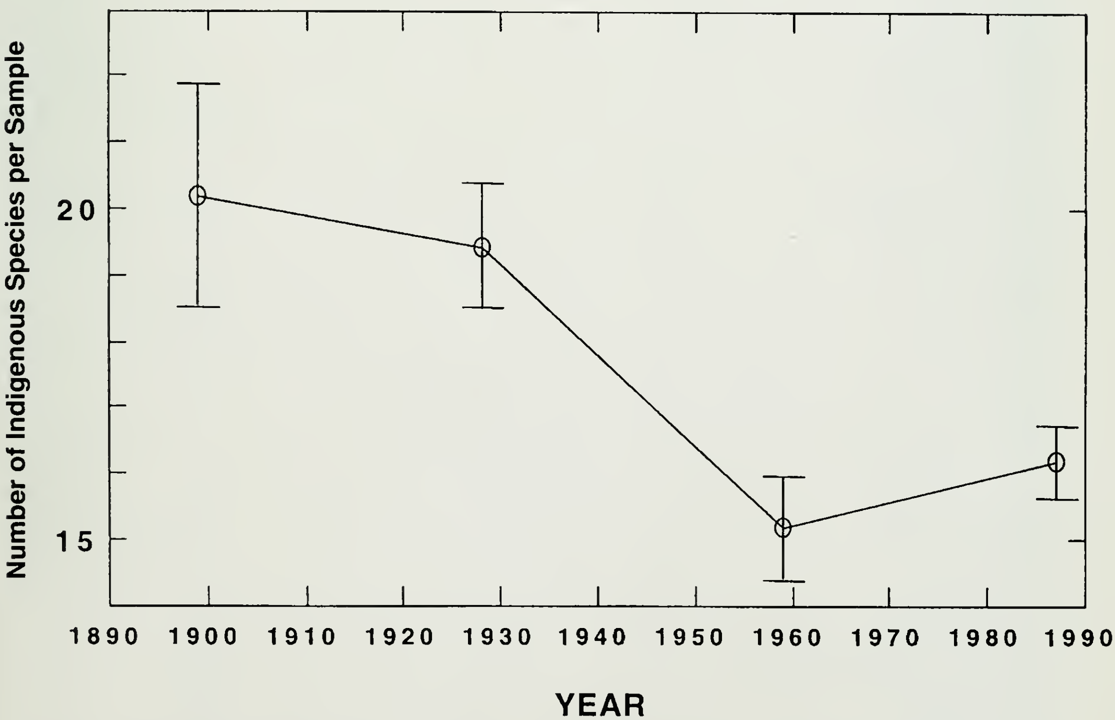


Figure 6. Mean numbers of indigenous fish species per sample after correction for gear efficiency for each of four surveys in Champaign County streams. Error bars are standard errors.

Table 3. Numbers of samples (nonrepeated within surveys) containing species or species pairs (80 taxa from 463 samples) in the four surveys.

Survey and number of samples	Forbes & Richardson n= 46	Thompson & Hunt n=125	Larimore & Smith n=151	Larimore & Bayley n=141	Total n=463
Species					
Shortnose gar	0	0	0	1	1
Gizzard shad	1	0	8	23	32
Central stoneroller	19	63	94	75	251
Red shiner	0	0	15	13	28
Steelcolor/Spotfin shiner	32	52	58	79	221
Carp	5	8	49	34	96
Silverjaw minnow	22	75	67	48	212
Mississippi silvery minnow	4	9	8	0	21
Bigeye chub	4	7	0	0	11
Pallid shiner	0	1	0	0	1
Striped shiner	9	55	81	113	258
Mimic shiner	0	0	3	0	3
Redfin/Ribbon shiner	9	66	88	67	230
Silver chub	1	0	0	0	1
Hornyhead chub	10	46	64	57	177
Golden shiner	20	39	39	11	109
Emerald shiner	0	3	0	0	3
Bigeye shiner	0	2	0	0	2
Bigmouth shiner	0	5	26	18	49
Blacknose shiner	1	0	0	0	1
Rosyface shiner	0	0	6	0	6
Sand shiner	23	44	77	76	220
Pugnose minnow	0	1	0	0	1
Suckermouth minnow	16	23	28	23	90
Bluntnose minnow	38	105	123	112	378
Fathead minnow	3	20	18	4	45
Bullhead minnow	4	3	0	0	7
Creek chub	9	99	121	94	323
River carpsucker	0	0	0	5	5
Quillback	10	9	45	33	97
Highfin carpsucker	7	4	29	11	31
White sucker	16	62	47	41	166
Creek chubsucker	21	44	76	59	200
Northern hogsucker	6	26	39	28	99
Bigmouth buffalo	0	0	0	2	2
Black buffalo	0	1	0	0	1
Spotted sucker	14	3	1	9	27
Silver redhorse	0	0	3	11	14
Golden redhorse/Black redhorse	7	20	49	32	108
Shorthead redhorse	4	4	0	10	18
Black bullhead	11	12	4	17	44
Yellow bullhead	7	14	30	69	120
Channel catfish	4	7	13	12	36

(*Table 3 continued*)

Survey and number of samples	Forbes & Richardson n= 46	Thompson & Hunt n=125	Larimore & Smith n=151	Larimore & Bayley n=141	Total n=463
Species					
Slender madtom	0	3	0	0	3
Stonecat	1	5	17	12	35
Tadpole madtom	11	7	18	30	66
Brindled madtom	6	0	5	6	17
Freckled madtom	0	0	0	5	5
Flathead catfish	0	0	3	2	5
Grass pickerel	5	24	14	58	101
Pirate perch	0	12	11	12	35
Blackstripe topminnow	14	40	50	98	202
Mosquitofish	0	0	2	0	2
Brook silverside	6	2	1	2	11
White bass	0	0	0	7	7
Rock bass	0	0	15	15	30
Green sunfish	25	36	69	83	213
Warmouth	1	0	0	0	1
Orangespotted sunfish	14	13	6	8	41
Bluegill	1	1	10	44	56
Longear sunfish	17	36	50	101	204
Redear sunfish	0	0	1	3	4
Smallmouth bass	1	16	36	28	80
Largemouth/Spotted bass	4	3	19	35	61
White crappie	2	2	9	8	21
Black crappie	4	2	0	2	8
Eastern sand darter	0	2	1	0	3
Mud darter	2	0	1	1	4
Blackside darter	14	23	44	13	94
Greenside darter	9	8	13	3	33
Rainbow/Orangethroat darter	7	32	59	37	135
Bluntnose darter	0	1	0	0	1
Fantail darter	4	13	15	1	33
Slough darter	0	1	0	0	1
Johnny darter	23	80	74	42	219
Banded darter	0	8	3	0	11
Logperch	1	2	6	3	12
Slenderhead darter	2	7	16	3	28
Dusky darter	1	0	0	3	4
Freshwater drum	0	3	1	13	17

Table 4. Tests of association (using contingency tables of species presence/absence) and time trends (using logistic-linear regression) for all four surveys. Shown are percentages of numbers of samples, nonrepeated (different sites) within surveys, in which each species was encountered. The 47 species or species pairs shown occurred in five or more samples in two or more surveys. (These are multiple tests, consequently Bonferroni-adjusted probabilities were assigned to the original *P*-valu shown for each Chi-squared estimate to provide the following significances: * = .05, ** = .01, *** = .001, blank = not significant at *P*=0.05.)

Survey:	Forbes & Richardson	Thompson & Hunt	Larimore & Smith	Larimore & Bayley	Association Tests		Time Trend Tests	
Number of samples	46	125	151	141	CHI- SQ	*P*	CHI-SQ	*P*
Species								
Trend of Increasing Occurrence								
Longear sunfish	37.0	28.8	33.1	71.6	63.6	<0.00001***	40.0	<0.00001***
Bluegill	2.2	0.8	6.6	31.2	71.9	<0.00001***	68.5	<0.00001***
Rock bass	0.0	0.0	9.9	10.6	18.8	0.00029*	17.1	0.000036***
Largemouth/Spotted bass	8.7	2.4	12.6	24.8	30.3	<0.00001***	25.5	<0.00001***
Striped shiner	19.6	44.0	53.6	80.1	65.7	<0.00001***	65.4	0.00001***
Red shiner	0.0	0.0	9.9	9.2	17.5	0.00055*	14.1	0.00018**
Bigmouth shiner	0.0	4.0	17.2	12.8	18.9	0.00029*	11.4	0.00072*
Common carp	10.9	6.4	32.5	24.1	31.9	<0.00001***	14.7	0.00013**
Blackstripe topminnow	30.4	32.0	33.1	69.5	55.3	<0.00001***	38.5	<0.00001***
Grass pickerel	10.9	19.2	9.3	41.1	48.5	<0.00001***	23.4	<0.00001***
Gizzard shad	2.2	0.0	5.3	16.3	30.9	<0.00001***	29.7	<0.00001***
Yellow bullhead	15.2	11.2	19.9	48.9	62.5	<0.00001***	57.2	<0.00001***
Trend of Decreasing Occurrence								
Orangespotted sunfish	30.4	10.4	4.0	5.7	33.1	<0.00001***	19.2	0.000012***
Golden shiner	43.5	31.2	25.8	7.8	34.1	<0.00001***	31.9	<0.00001***
Silverjaw minnow	47.8	60.0	44.4	34.0	18.2	0.00040*	12.1	0.00049*
Spotted sucker	30.4	2.4	0.7	6.4	60.8	<0.00001***	12.6	0.000039*
Johnny darter	50.0	64.0	49.0	29.8	31.6	<0.00001***	21.5	<0.00001***
Complex Change: Decreasing Early and/or Increasing Later								
Green sunfish	54.3	28.8	45.7	58.9	25.6	0.000012***	9.50	.0021
Steelcolor/Spotfin shiner	69.6	41.6	38.4	56.0	19.8	0.00018**	0.00	.950
Black bullhead	24.0	9.6	2.7	12.1	20.0	0.00014**	2.50	.110
Brindled madtom	13.0	0.0	3.3	4.3	16.4	0.0095*	0.50	.420
Tadpole madtom	23.9	5.6	11.9	21.3	17.5	0.00055*	2.70	.10
Complex Change: Increasing Early and/or Decreasing Later								
Creek chub	19.6	79.2	80.1	66.7	68.6	<0.00001***	9.70	.0018
Redfin/Ribbon shiner	19.6	52.8	58.3	47.5	21.9	0.000068**	4.00	.047
Other Complex Changes								
Quillback	21.7	7.2	29.8	23.4	21.9	0.000067**	5.60	.018
Blackside darter	30.4	18.4	29.1	9.2	21.2	0.000096**	7.10	.0074
Greenside darter	19.6	6.4	8.6	2.1	16.7	0.00082*	10.4	.0012

(Table 4 continued)

	Forbes & Richardson	Thompson & Hunt	Larimore & Smith	Larimore & Bayley	Association Tests	
	Nonsignificant Association and No Trend at P=0.05					
Smallmouth bass	2.2	12.8	23.8	19.9	14.2	0.003
White crappie	4.3	1.6	6.0	5.7	3.6	0.31
Bluntnose minnow	82.6	84.0	81.5	79.4	1.0	0.81
Central stoneroller	41.3	50.4	62.2	53.2	7.8	0.050
Fathead minnow	6.5	16.0	11.9	2.8	14.6	0.0022
Hornyhead chub	21.7	36.8	42.4	40.4	6.8	0.079
Sand shiner	50.0	35.2	51.0	53.9	10.8	0.013
Suckermouth minnow	34.8	18.4	18.5	16.3	8.0	0.047
Mississippi silvery minnow	8.7	7.2	5.3	0.0	10.8	0.013
Highfin carpsucker	15.2	3.2	6.0	7.8	8.2	0.042
Northern hog sucker	13.0	20.8	25.8	19.9	3.9	0.27
Black/Golden redhorse	15.2	16.0	32.5	22.7	12.5	0.0058
White sucker	34.8	49.6	31.1	29.1	14.6	0.0022
Creek chubsucker	45.7	35.2	50.3	41.8	6.6	0.0855
Rainbow/Orangethroat darter	15.2	25.6	39.1	26.2	12.9	0.0049
Fantail darter	8.7	10.4	9.9	0.7	12.8	0.0052
Slenderhead darter	4.3	5.6	10.6	2.1	9.6	0.022
Pirate perch	0.0	9.6	7.3	8.5	4.7	0.19
Stonecat	2.2	4.0	11.3	8.5	7.3	0.063
Channel catfish	8.7	5.6	8.6	8.5	1.1	0.77

Twelve taxa indicated general increases in percentage occurrence through time (Table 4). As examples, the occurrences of striped shiner, grass pickerel, blackstripe topminnow, and bluegill are shown in Figure 7a. General decreases were observed in five taxa, including, as examples, the golden shiner and orange-spotted sunfish (Figure 7b). Five taxa, showing more complex changes, appeared to decrease early and/or increase later. Examples of this pattern are the green sunfish and tadpole madtom (Figure 7c). Two taxa, the creek chub and redfin/ribbon shiner composite, appeared to increase early and/or decrease later (Figure 7d). Two species, the red shiner and rock bass, were first collected during the third survey, so of course they increased late in the series. Other taxa showed no definite trend. Nearly one-half of the taxa examined showed nonsignificant association in occurrence and no trend at p=0.05. Nonsignificance from this test does not rule out possible changes during part of the time series. For example, the silvery minnow occurred during the first three surveys, but none was found in the present survey.

The changes in occurrence listed in Table 4 might be in responses to changes in habitat or biota. The fact that some taxa generally decreased suggests their environment was deteriorating, for those that increased is the suggestion that the specific requirements of their environment were improving. We will later associate these trends with environmental information that can explain some of the regional differences among drainages illustrated in Appendix 2.

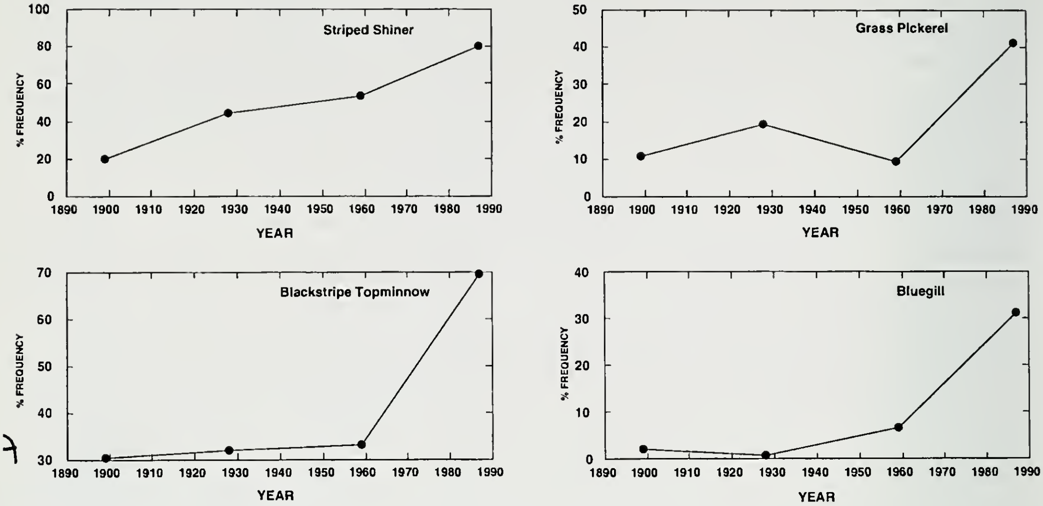
Comparisons Between 1959 and This Study

Results from 75 stations that were sampled in 1959 with the 30-ft electric seine and documented sufficiently for efficiency corrections were compared with samples from the current study from the same stations. Efficiency corrections were made to all 150 samples according to equations derived by Bayley and Dowling (1990, 1993) based on 75 calibrations, many of which were conducted in Champaign County streams.

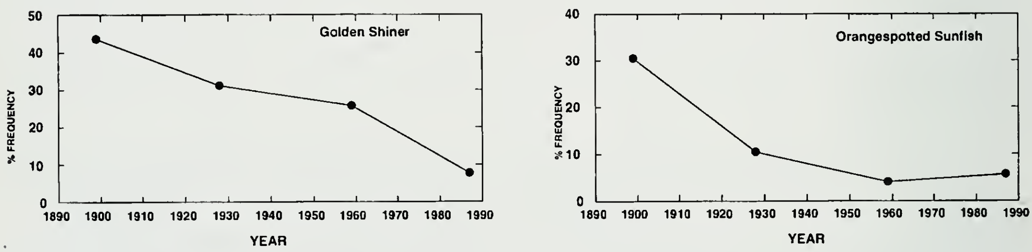
Abundance and biomass were compared at each site on a per-unit-stream-length basis, so that short-term discharge differences that affect fish quantities per unit area at each

(Continued on page 75)

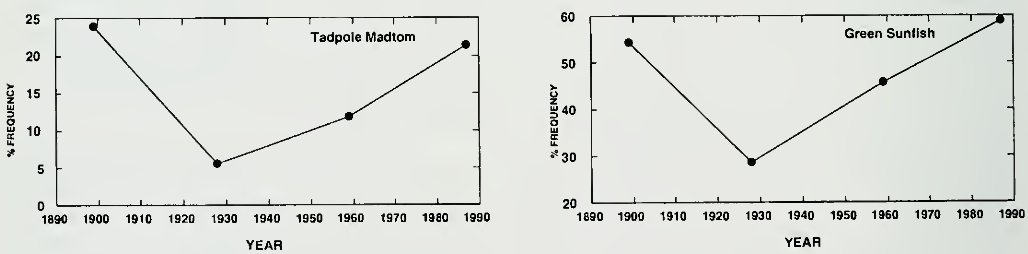
Figure 7



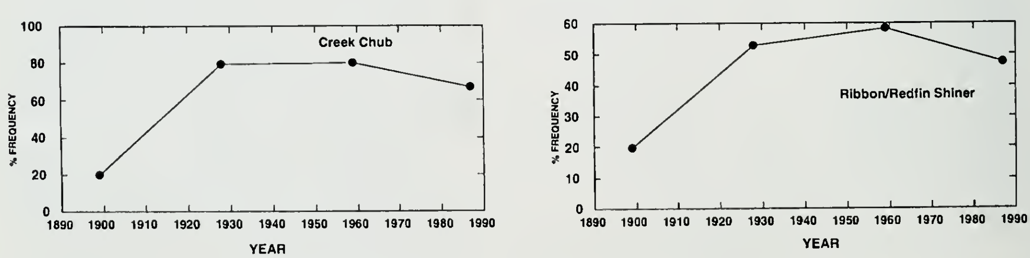
7a. Trend of increasing occurrence.



7b. Trend of decreasing occurrence.



7c. Complex change, decreasing and/or increasing later.



7d. Complex change, increasing and/or decreasing later.

Table 5. Comparisons between 75 replicated sites of current study and those of Larimore and Smith using t-pair tests (positive t-value indicates mean of 1987/88 samples higher than 1959).

Item	t-pair	DF	*P*
Cross-section area	1.551	74	0.125
Estimated richness	0.127	74	0.900
Measured richness	0.533	74	0.595
Prey numbers	-1.006	73	0.318
Prey biomass	0.852	73	0.397
Total numbers (less darters)	-1.448	73	0.152
Total biomass (less darters)	2.335	73	0.022*
Large predator species:			
Smallmouth bass numbers	1.273	74	0.207
Smallmouth bass biomass	3.289	74	0.002*
Spotted bass numbers	-1.001	74	0.320
Spotted bass biomass	2.058	74	0.043
Largemouth bass numbers	0.902	74	0.370
Largemouth bass biomass	1.840	74	0.070
Rock bass numbers	0.888	74	0.377
Rock bass biomass	1.693	74	0.095
Channel catfish numbers	2.285	74	0.025
Channel catfish biomass	2.884	74	0.005*
Grass pickerel numbers	3.276	74	0.002*
Grass pickerel biomass	6.186	74	0.000**

* significance at p=0.05, ** significance at p=0.01. Results for six predators adjusted for Bonferroni significance levels (i.e., significance at 0.05 level requires $p < 0.05/6$).

survey would be avoided. No significant difference in discharge between 1959 and 1987/88 was identified, based on t-paired comparison of cross sectional area (p=0.125, Table 5).

It should be noted that 2 of the 75 replicates were taken in the drought year of 1988, but that these were in the lower Salt Fork, which was not as measurably affected by the drought (Bayley and Osborne 1993).

The results from t-paired analyses of the 75 sites showed changes neither in species richness nor in prey (all species except predators listed and darters) number or biomass (Table 5), but total biomass increased significantly. This is partly explained by the overall biomass increase in the six large predator species (Figure 8). Although some increases were not significant, the sign test of all six species was positive at p=0.03. Grass pickerel, channel catfish, and smallmouth bass had the most significant increases in biomass. Increases in numbers (Figure 9) were often not significant, implying that conditions had improved for larger individuals.

This analysis suggests that large predators, mostly sportfishes, have increased since 1959. These densities are still low compared to the higher-gradient Illinois streams with coarse substrates and greater habitat diversity, the latter having been drastically reduced when the streams were dredged around the turn of the century. As will be discussed later, improvements in water quality since the 1960s may account for much of this increase in large predators. Gammon (1993) also showed an increase in sportfishes between 1971 and 1989 in the upper Wabash River in Indiana above and below where it receives the Salt Fork River.

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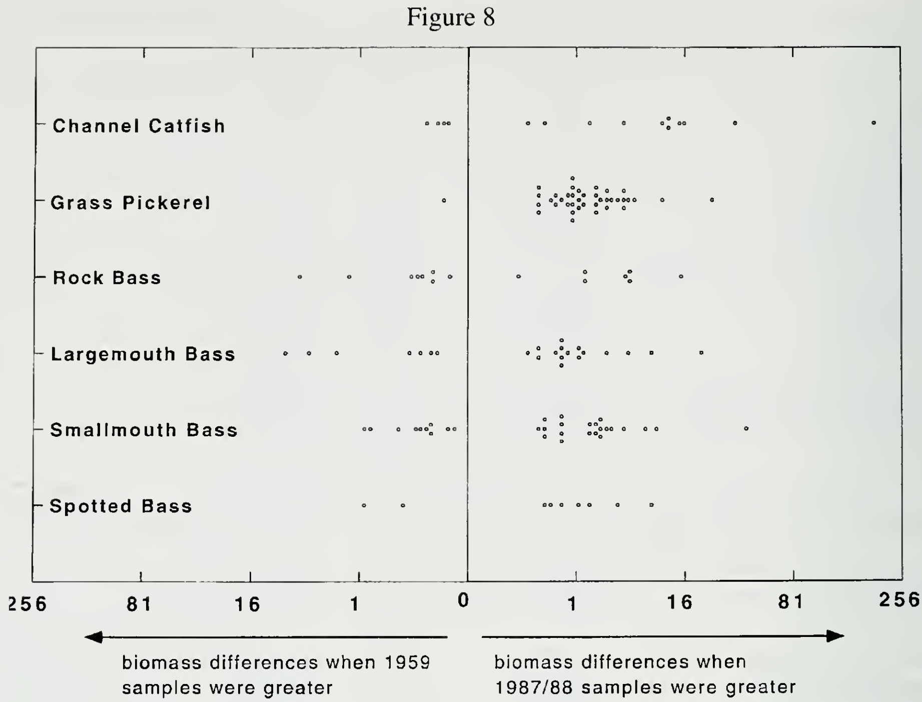

Figure 8. Differences in biomass (g) per linear foot of stream between same sample sites in 1959 and 1987/88 (positive differences shown on cube-foot scales, samples with zeros in both surveys omitted).

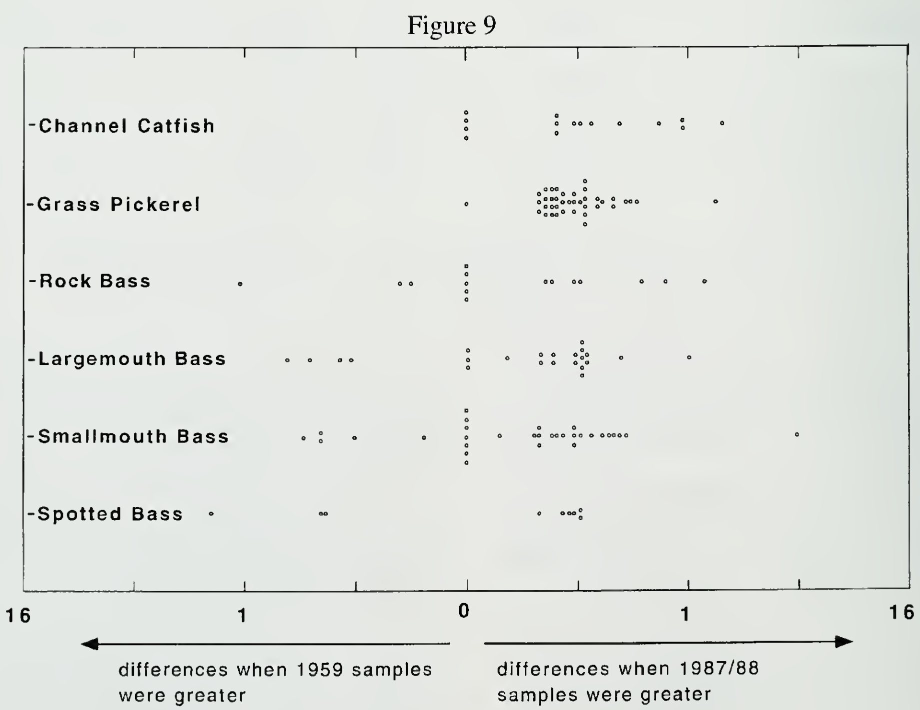

Figure 9. Differences in numbers of individuals per linear foot of stream between same sample sites in 1959 and 1987/88 (positive differences shown on cube-foot scales, samples with zeros in both surveys omitted).

LAND USE AND STREAM HABITATS

About the time of the third survey, biologists were realizing that management of the stream fish populations depended on management of the stream's watershed, and, as Larimore (1960) pointed out, involves "virtually everything in the watershed and especially the effects of the attitudes and works of man." The environment of the minnow or mayfly does not end at the stream bank but extends up across the farmer's field to his barn lot and to the village streets. A fundamental characteristic of all streams is the capacity to integrate watershed patterns and processes (Wiley et al. 1990). Thus, land-use and cultural modifications occurring within a watershed ultimately influence the quality of the stream environment and fish habitat.

Larimore and Smith (1963) reviewed the general changes in land use that occurred in Champaign County prior to 1960. The principal changes included increases in urbanization and industrialization and associated pollution, and decreases in forested and undrained lands. These changes were similar to those in watersheds in other midwestern states during this same period. The recent advent of computer-based geographical information systems (GIS) has provided researchers with the capabilities of accurately and rapidly addressing land-use and cover patterns. Documenting such changes in land use and comparing them to qualitative changes in fish community composition and structure provide valuable insights into the influence of landscape modifications on fish community structure.

Subtle sociological changes also have been instituted during the past 30 years, including passage of more stringent environmental laws (e.g., Toxic Substance Control Act, Clean Water Act), advances and implementation of municipal waste treatment, reduction or elimination of the use of persistent chloro-organic pesticides, constraints on the degree and extent of permissible channel modifications, and promotion of conservation farming practices that may reduce sediment loading in streams. While there have been obvious changes in cultural practices, there has been inadequate quantification of instream habitat conditions during the previous sampling programs. This lack of historical data does not permit a valid assessment and determination of changes in instream habitat. Therefore, a primary objective of this study was to quantify local instream habitat conditions at several fish sampling stations in an attempt to identify environmental variables controlling the structure of stream fish communities.

Land-use and land-cover patterns for Champaign County were interpreted and analyzed for two time periods to provide insight into changes that have occurred in the study area since Larimore and Smith's fish community study of 1959. These time periods, late 1950s (referred to throughout text as historical) and mid-1980s (referred to throughout text as modern), approximate the period when the third and fourth surveys of the fishes of Champaign County were conducted.

Methods

Watershed boundaries were determined by joining modern 7.5-minute topographic maps and following the contour lines to determine the drainage basins for each station. Station watersheds extending outside the boundaries of Champaign County were also included in all analyses. Land-use/cover patterns were interpreted from the same maps for the 1980s and from 15-minute (1:64,000) U.S. Geological Survey topographic maps produced between 1950 and 1958 (except the Monticello quadrangle produced in 1948), which were used for the historical analysis. All land-use/cover patterns were drawn on computer-generated plots of each specific map quadrangle and digitized using ARC/INFO software (Environmental Systems Research Institute).

For modern and historical coverages, land-use/cover patterns were categorized according to the LUDA system (Anderson et al. 1976). Five land-use categories were employed in the present study: urban and built-up land, agricultural land, forest land, water (lakes, reservoirs, and streams), and barren lands (e.g., gravel pits). Land-use/cover patterns were digitized as polygons (enclosed areas), stream networks as line coverages, and sites as point coverages. All digitized coverages were converted to a standardized geographic reference scale (Lambert feet) and merged with adjacent coverages of the same type (i.e., polygon, line, or point) to form a single coverage representing watershed land-use/cover patterns, stream network, and sampling sites in Champaign County.

The total acreage of the drainage area of each station and the total area of each land-use/cover category in each sampling station for each era (modern and historical) were determined using ARC/INFO software. The data from the two time periods were compared to provide an overall assessment of changes in each land-use category over the 30-year period and for each of the six drainage basins in Champaign County.

Because of the importance of riparian vegetation to stream fish communities, we investigated changes in land cover at varying distances from the stream over the 30-year period. Land-use/cover patterns within 100, 200, and 400 ft of the stream channel were determined using the ARC/INFO "buffer" facility for each station watershed. Total acreage and percentage of each land use for each stream buffer and watershed were calculated and data from the modern era were compared to those from the historical coverage to determine changes in land use adjacent to stream channels.

County-wide Changes

The total area of land encompassed by the watersheds of the Champaign County sampling stations was 856,264 acres. This value includes areas of the watersheds that extended upstream into neighboring counties. In the late 1950s, 19,699 acres (2.3%) were urban, 824,051 acres (96.2%) were agriculture, 11,722 acres (1.4%) were forested, 574 acres (0.1%) were water, and 218 acres (0.03%) were barren land. By contrast, modern land-use patterns (Figures 5 and 10) within the same study area consist of 27,059 acres (3.2%) urban land, 817,174 acres (95.4%) agriculture, 10,715 acres (1.3%) forest, 1,030 acres (0.1%) water, and 496 acres (0.06%) barren land.

Over the past 30 years, the acreage in three land-use categories has increased while two have decreased (Figure 11). The greatest absolute change was in the urban land-use category, which increased by 37.4% or an additional 7,360 acres. Surface waters increased by 79.5%, or an additional 456 acres; most was from the creation of Homer Lake, borrow pits during the construction of interstate highways, and the development of farm ponds. The third category that increased in acreage during the past 30 years was barren land, which increased by 126.9% or 277 acres, the single largest proportional increase in any of the land-use categories but comprising a very small proportion of the county. Acreage in agricultural and forested lands decreased by 6,876 acres (0.8%) and 1,007 acres (8.6%), respectively (Figure 11). The low proportional decrease in agricultural land relative to the change in actual acreage reflects the dominance of agricultural land use within the region. Approximately 74 miles of interstate highways were constructed on agricultural land during this 30-year period but are not considered in this analysis.

Changes among drainage basins. The Sangamon River basin measuring 259,159 acres (which includes the part of the upper basin in the neighboring county), is the largest basin in the study area, while the Little Vermilion River is the smallest basin, measuring 16,577 acres. The Salt Fork River basin is 225,660 acres, the Embarras River basin 88,990 acres, the Kaskaskia River basin 97,334 acres, and the Middle Fork River basin 168,758 acres (Figure 12).

The greatest proportional changes in land use among the six basins were in the water and barren categories. The high proportional changes in both categories were the result of the small amount of lands in these land uses in the 1950s, which made even minor changes proportionally large. In these categories, the greatest proportional change was in the Salt Fork basin, where acreage in both land-use categories increased. The greater increase in the amount of water in the Salt Fork basin was

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Figure 10

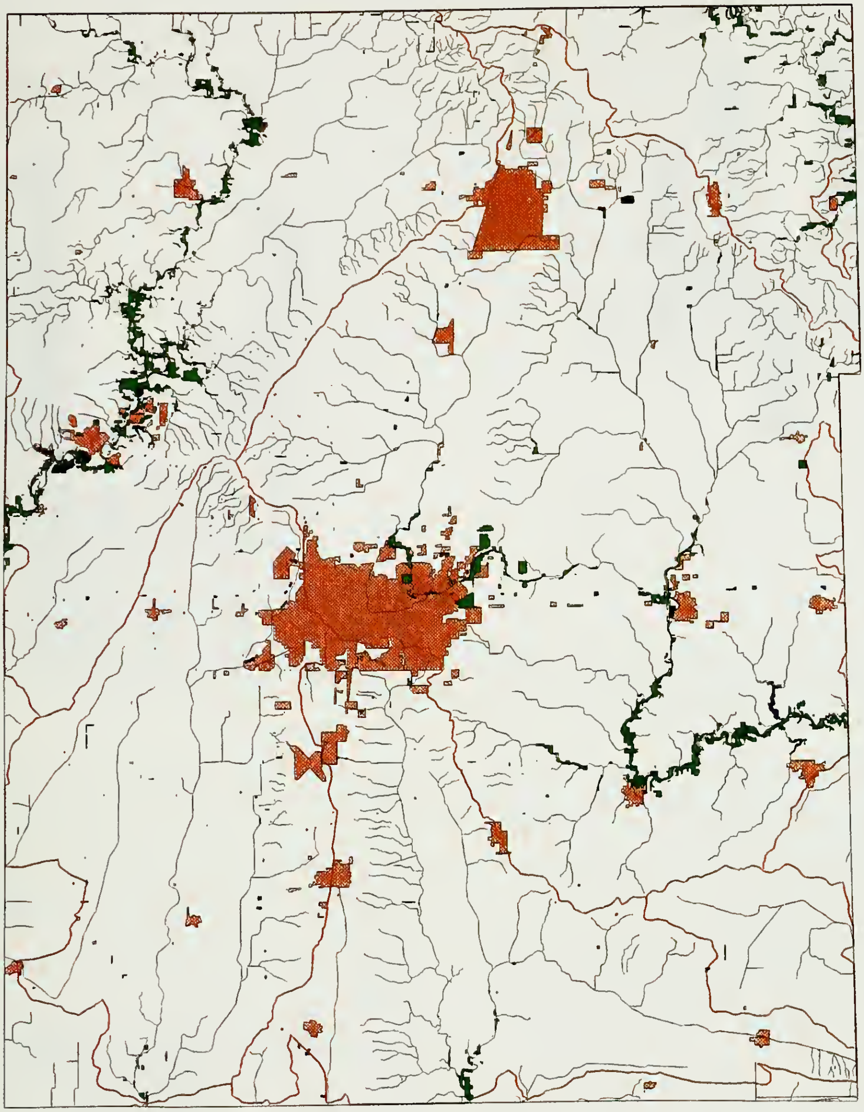

Figure 10. Present day forest (green) and municipalities (red) in Champaign County.

Figure 11

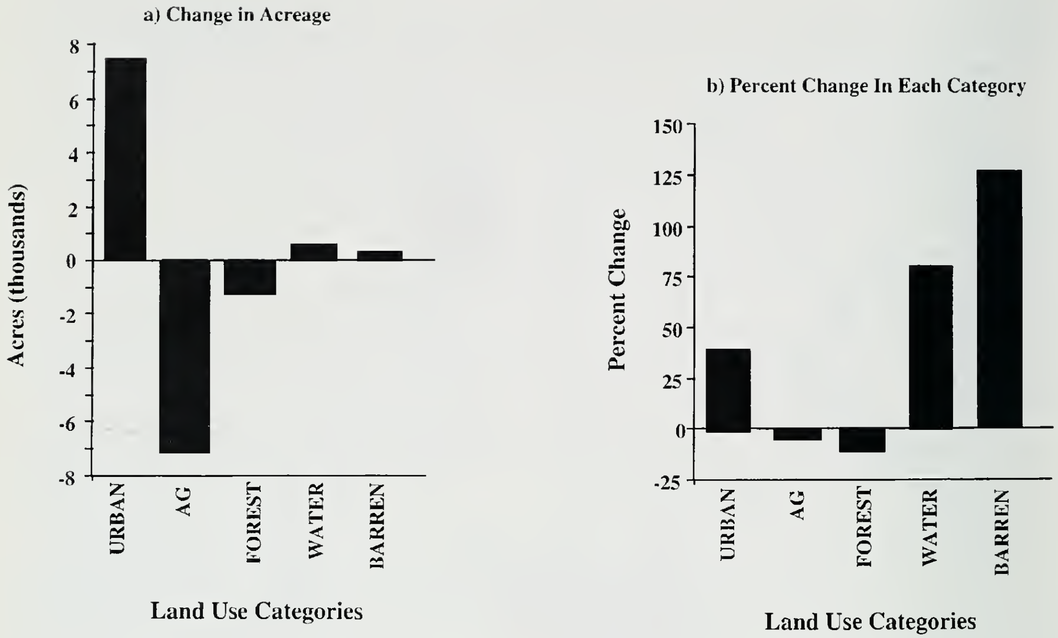

Figure 11. Net changes in the amount of land within each land-use category between the late 1950s and the 1980s. Data are presented by (a) absolute acreage, and (b) percent change within each category.

largely due to the construction of Homer Lake (102 acres) in the eastern portion of the county. Barren land, although small in total area, displayed a dramatic proportional increase in the Salt Fork over the 30-year period. This increase was associated with the growth and expansion of the Champaign-Urbana sanitary landfill system. This land use also increased in the Sangamon and Middle Fork drainage basins.

Urbanization increased in all drainage basins except the smallest, the Little Vermilion. The decrease in urbanization in this basin was the result of the conversion of several farm homesteads to agricultural land use. As a result, unlike the other basins, the Little Vermilion displayed an increase in the proportion of land in agricultural use. The greatest proportional increases in urbanization were in the Embarras and Kaskaskia River basins, reflecting the western and southern expansion of the Champaign-Urbana area. This increase in urban land in the Kaskaskia River and Embarras River basins corresponded to the decrease in the proportion of land in agriculture (Figure 12). Although a 1-2% reduction did occur in the amount of land being used for agriculture, this proportional loss was insignificant relative to the 40-80% loss of forested lands that occurred in the Embarras, Little Vermilion, and Kaskaskia River basins. Less dramatic decreases in forested lands were also observed in the Salt Fork and Sangamon River basins. A small increase in the proportion of land in forest was reported in the Middle Fork River basin; this can be attributed to the creation of a county park in the northeastern portion of the county.

These data indicate that the general pattern of change in land use within the study area was for urban, water, and barren categories to increase and for agricultural and forest land to decrease. While this was the pattern within the study area as a whole, some interbasin differences in the amount of change in land uses were also evident. Most apparent was the substantial growth in urban land use in the Kaskaskia and Embarras basins, which resulted

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Figure 12

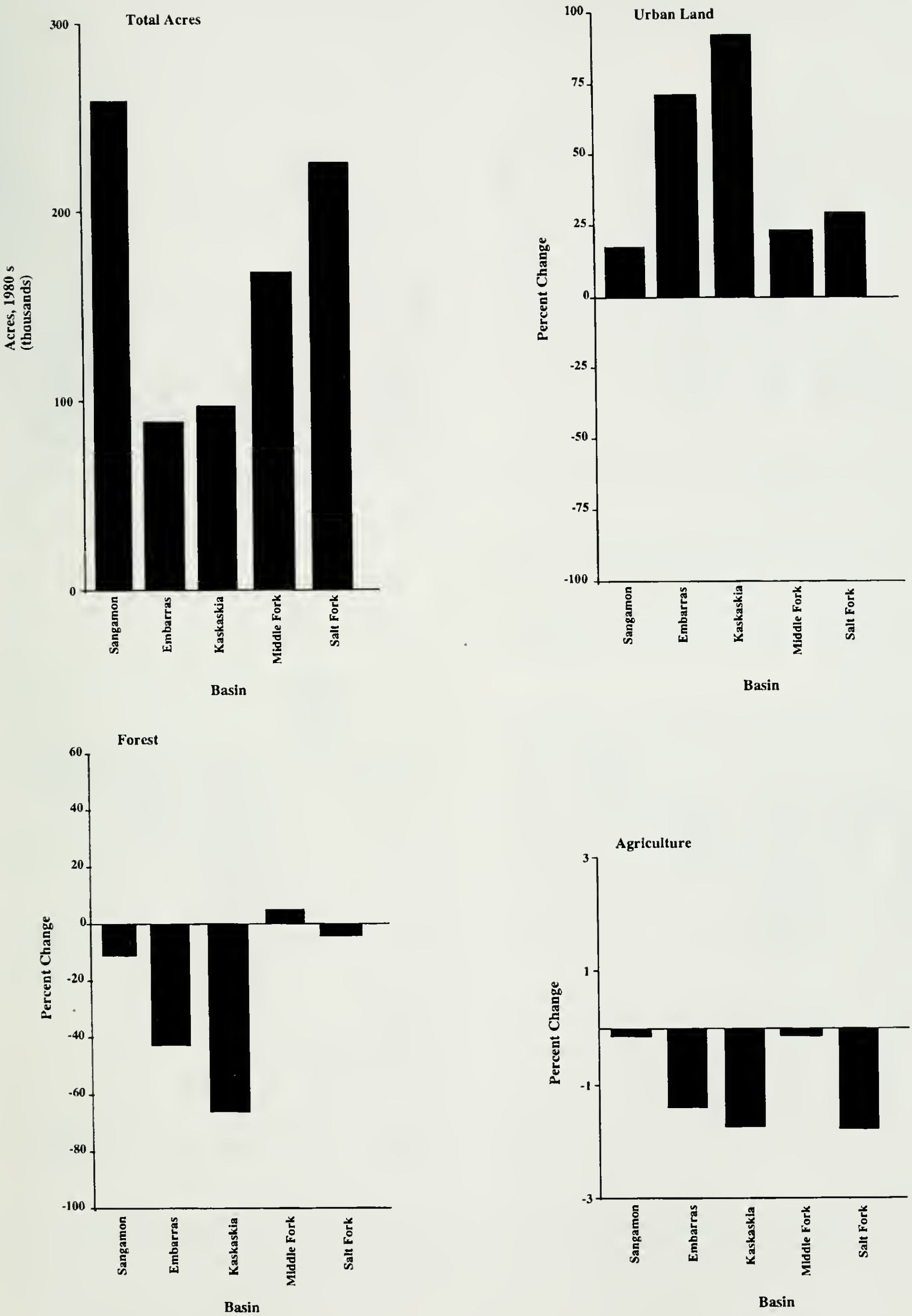

Figure 12. Total acres and percent net change for each land-use category (acres) of each basin between the 1950s and 1980s.

in a small proportional loss of agricultural land. With the exception of a slight increase in the Middle Fork basin, the greatest proportional loss across basins was the amount of forest land.

Changes Within Riparian Buffer Strips

The proportions of land converted to urban land use were substantially higher in the 100-, 200-, and 400-ft buffers (Figure 13) than were the basinwide averages of urban land use (Figure 12) for the Embarras, Kaskaskia, Middle Fork, and Salt Fork basins. These results demonstrated that a disproportionately higher amount of urbanization has occurred in the immediate vicinity of stream channels in most of the study area compared to other portions of the watershed. Because urbanization has been associated with the degradation of aquatic ecosystems (e.g., Karr and Dudley 1978; Osborne and Wiley 1988; Osborne and Herricks 1989), the conversion of lands adjacent to stream channels to urban areas can be expected to have a greater impact on stream-fish communities than would development in areas more distant from stream channels.

Unlike the urban category, there were minimal differences in the proportional change in the agriculture category in riparian areas relative to basinwide averages (Figures 12 and 13). The exception was in the Sangamon River basin. Despite a slight overall loss for the whole Sangamon watershed, the proportion of land in agricultural use increased adjacent to stream channels. An increase in agricultural land adjacent to stream channels also corresponded to a net loss in forest land use, suggesting that a substantial proportion of the riparian forest was lost when the Sangamon River basin was further converted to agricultural use. The removal of riparian vegetation can be expected to have had substantial impacts on the integrity of the Sangamon River and its biotic communities (Schlosser and Karr 1981). Loss of riparian vegetation during the past 30 years was not limited to the Sangamon River basin, nor was it only associated with conversion to agricultural land use (Figure 13). In the Little Vermilion basin, 100% of the forest land within 200 ft of the stream channel was lost and mostly converted to agriculture. Even though the Little Vermilion was the smallest basin within the study area, that trend of converting riparian forest to agricultural land should increase our concern about its effects on water quality throughout the Midwest (Kovacic et al. 1990; Osborne and Kovacic 1993; Schlosser and Karr 1981). Similarly, a disproportionate loss of riparian forests, changing to agricultural and urban areas, appears to have occurred in the Kaskaskia River basin (Figures 12 and 13).

Summary of Land-use Changes

Changes in land-use patterns in Champaign County indicate that riparian vegetation has suffered significant losses during the past 30 years as a result of conversion of land to agricultural or urban uses. The exception to this pattern was in the Middle Fork basin, where a small riparian area was converted from agricultural use to forest land use.

PHYSIO-CHEMICAL HABITAT

Detailed assessments of physio-chemical habitat conditions were made at fish sampling stations. Because of the variation in environmental conditions associated with the 1988 drought, analyses that relate physio-chemical habitat and riparian land-use parameters to stream fish communities included data collected only in 1987. The Little Vermilion basin was not included in this habitat analysis because data were collected at only one station within the basin in 1987. Each of the five basins were represented by at least 10 sampling stations.

Habitat Assessment

Stream channel and riparian conditions were measured and described at 101 fish sampling stations in 1987, located among the five major drainages in Champaign County and including all locations quantitatively sampled by Larimore and Smith. Field measurements and visual estimates were made at each transect at each station (Table 6).

For each site and assessment date, a stream reach of approximately 100 m was divided into five equally-spaced transects.

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Figure 13

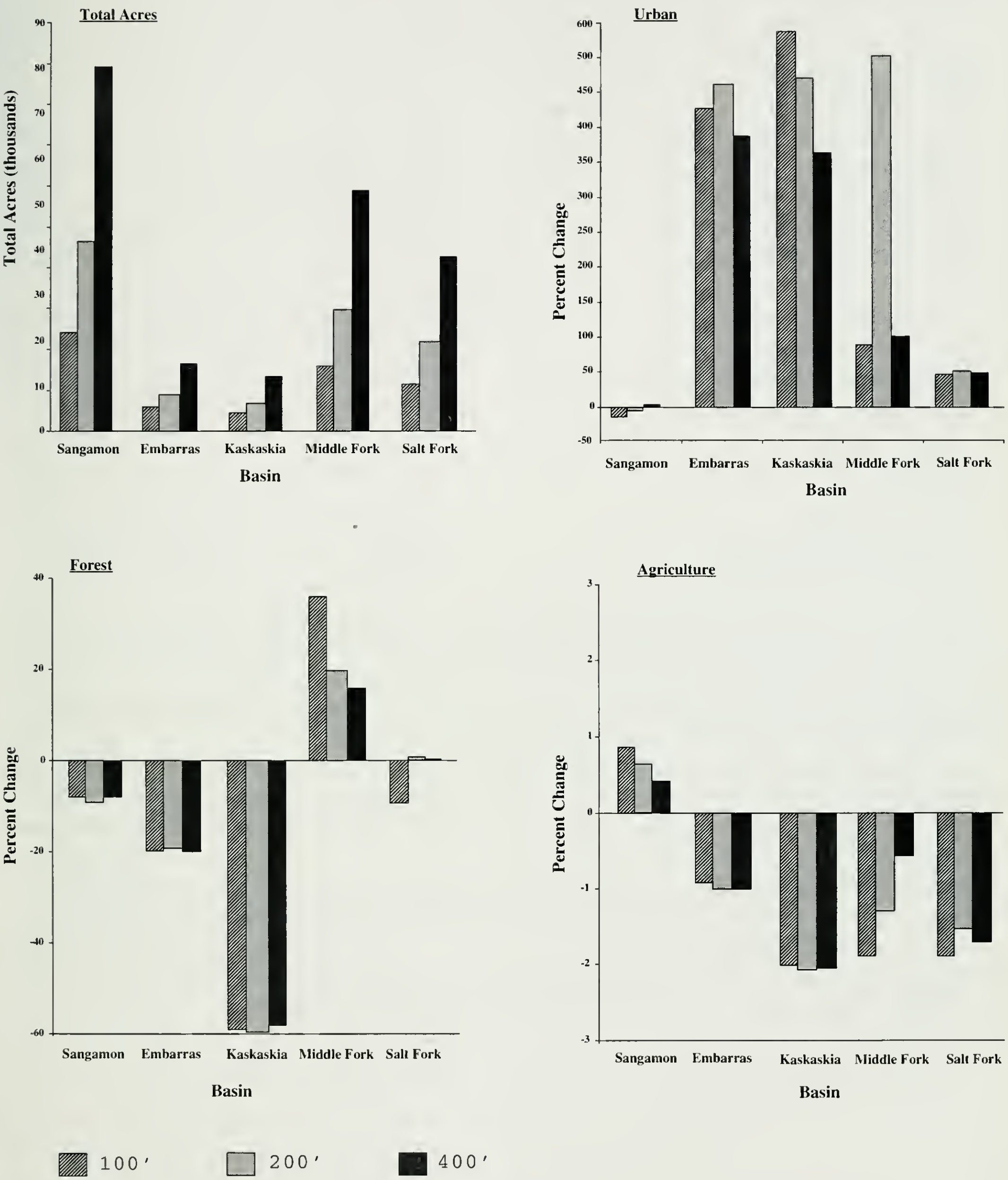

Figure 13. Net change in proportion of land within 100', 200', and 400' of streams between the 1950s and the 1980s in total acreage and in each land-use category with respect to major drainage basins.

Table 6. Parameters measured at each transect at each station. The mixture of units reflects the surveying and laboratory instruments used; they do not affect the multivariate analyses that standardize all units.

Parameter	Units
Directly measured	
Total width	ft
Shore water depth	cm
Bank undercut	cm
Vegetative overhang (1)	cm
Discharge	cfs
Cross-sectional profile	ft
Visually estimated	
Transect classification	riffle, run, glide, pool
Bank vegetative stability	1-4 rating
Streamside cover	1-4 rating
Channel vegetative cover (2)	%
Canopy (3)	%
Total shading (4)	%
Substrate type (5)	clay, silt, gravel, rubble, or boulders
Substrate compaction (6)	1-5 rating

1. Distance streamside vegetation (mostly herbaceous) extended directly over water.
2. The percentage of the stream channel at each transect covered by living or dead aquatic vegetation estimated visually. Water-surface cover and substrate cover included.
3. A visual estimate at each transect of the percentage of the water surface beneath woody bank vegetation > 1 m. Canopy density not considered in this estimate.
4. A visual estimate of the percentage by which total available light was reduced along the channel transect. This estimate considered shading due to canopy, channel vegetative cover, and bank height and slope, given the angle of the sun's path for the particular transect's compass angle and for the time of year.
5. Predominant substrate type determined visually and by touch along the transect where depth and velocity were measured. Substrate classified as one or a combination of the following: clay, silt, gravel, cobble, or boulder.
6. Substrate compaction rated at each measurement point along the transect. The rating was based on the degree to which one's foot, with little effort, penetrated the substrate.

When sites were accessed from a bridge crossing, the most downstream transect was approximately 30 m upstream of the bridge. Sampling commenced in an upstream direction beginning at the downstream end of a reach.

Weather and general flow conditions (high, moderate, or low) were noted during sampling. Air and water temperatures were taken with a mercury thermometer (with time noted). An assessment of fish habitat quality was made for the reach and the length of the reach measured.

Turbidity, dissolved oxygen, air and water temperature, and specific conductance were measured at sites when fishes were sampled. In addition, pH, alkalinity, nitrate (NO_3), nitrite (NO_2), ammonia (NH_3), and soluble reactive phosphorus (SRP) were determined for water samples from 97 stations in the summer and fall of 1987, including sites where Larimore and Smith took quantitative fish samples.

Water Chemistry. A Hach Model 16800 turbidimeter was used to determine turbidity of a sample that was collected prior to any instream work. A YSI Model 57 oxygen meter was used to measure dissolved oxygen. Air and water temperatures were measured with a mercury thermometer. Conductivity was measured with a YSI Model 33 S-C-T meter and adjusted for temperature. These measurements were taken only on days when fishes were collected.

For stations where more extensive water quality parameters were measured in 1987, samples were collected in Wheaton glass-stoppered bottles and transported on ice to the laboratory for immediate analysis. Total alkalinity and pH were determined with an ALTEX Model 3500 digital pH meter. Nutrients were measured with a HACH DR/3 portable water analysis instrument. The Salicylate Method was used to determine ammonia-nitrogen, the Diazotization Method (NitriVer 3 for concentrations of 0.0-0.2 mg/L) for nitrite-nitrogen, the Cadmium Reduction Method (NitraVer 6 for concentrations of 0.0-0.34 mg/L and NitraVer 5 for concentrations of 0.0-30.0 mg/L) for nitrate-nitrogen, and the Amino Acid Method for soluble reactive phosphorus.

Results

Box plots (Figure 14) were constructed for each physical and chemical habitat parameter from data collected at stations sampled in 1987 (Figures 15-18). Box plots are presented for the average values of each parameter occurring at stations within each of the five major drainage basins in Champaign County. The exception is for total residual chlorine (TRC), which was recorded in only three of the five drainage basins (Figure 18). The minimum and maximum recorded values within a basin are reflected in the bottom and top lines, respectively, of each box plot except for outliers, which are indicated by asterisks as used by Wilkinson (1989). The line bisecting the box itself designates the median value. The upper and lower edges of the box represent the median values of the upper and lower halves of the data, respectively.

Examination of the box plots of physical habitat parameters (Figures 15-18) reveals several pertinent characteristics of the streams in Champaign County. In general, there were minimal differences among stations across basins in most parameters examined. An obvious exception was the higher average total stream width at stations in the Middle Fork basin compared to stations in other basins (Figure 15). This higher width value reflects the fact that the Kaskaskia, Embarras, and Salt Fork basins, and a significant portion of the Sangamon basin, originate in the county and are composed of smaller, low-order streams. The Middle Fork originates north of Champaign County and is a mid-order stream where it enters the county. Slightly higher turbidity of the Middle Fork system was a coincidence of sampling time, for the Middle Fork is known to clear faster than the other streams of the county.

Conclusions

The most obvious characteristic of these streams was the limited variability in the parameters themselves, reflecting the homogeneous nature of stream habitat conditions within the county. For example, the streamside

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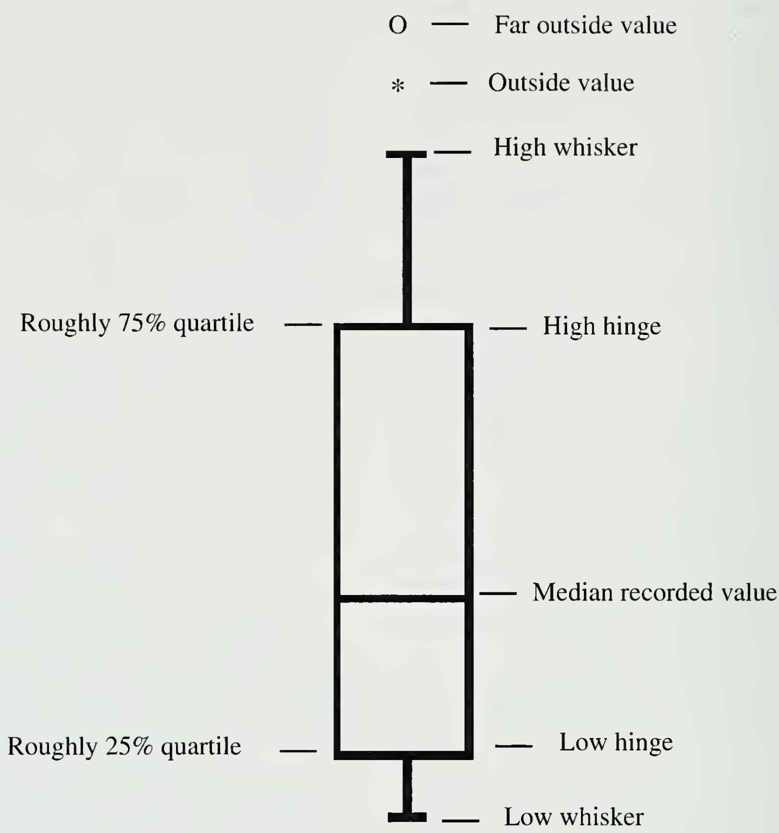
Figure 14



The "box" in a box plot extends from the low hinge (roughly the 25% point) to the high hinge (roughly the 75% point). The horizontal bar is at the median.

High and low hinges are the median values between the median and maximum and minimum values, respectively.

High and low whiskers are defined as:

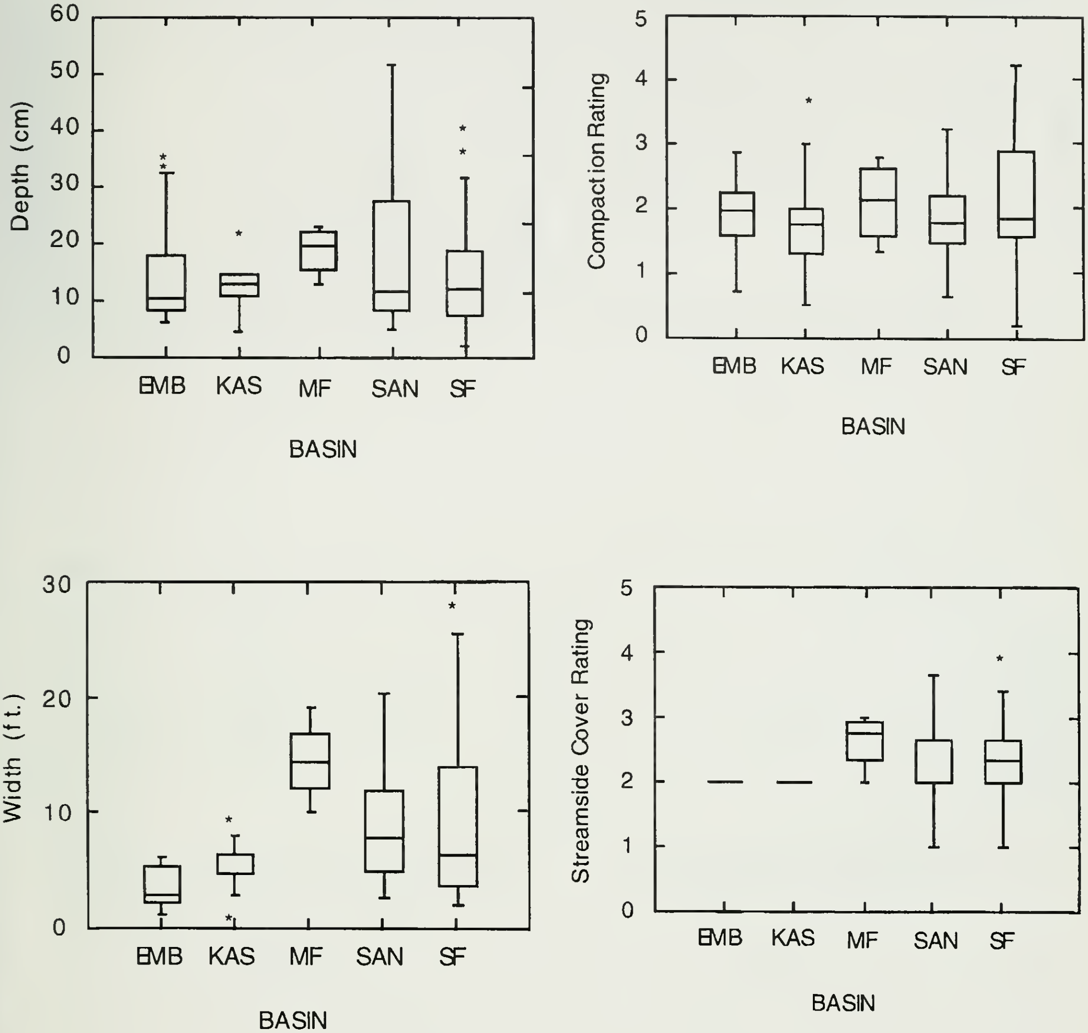
High whisker = high hinge +1.5(high hinge-low hinge),
Low whisker = low hinge -1.5(high hinge-low hinge).

Any data value beyond these limits is plotted with asterisks unless it exceeds either:

High hinge + 3.0(high hinge-low hinge)
or
Low hinge - 3.0(high hinge-low hinge)
in which case, it is plotted with a circle.

(As described by Wilkinson 1989.)

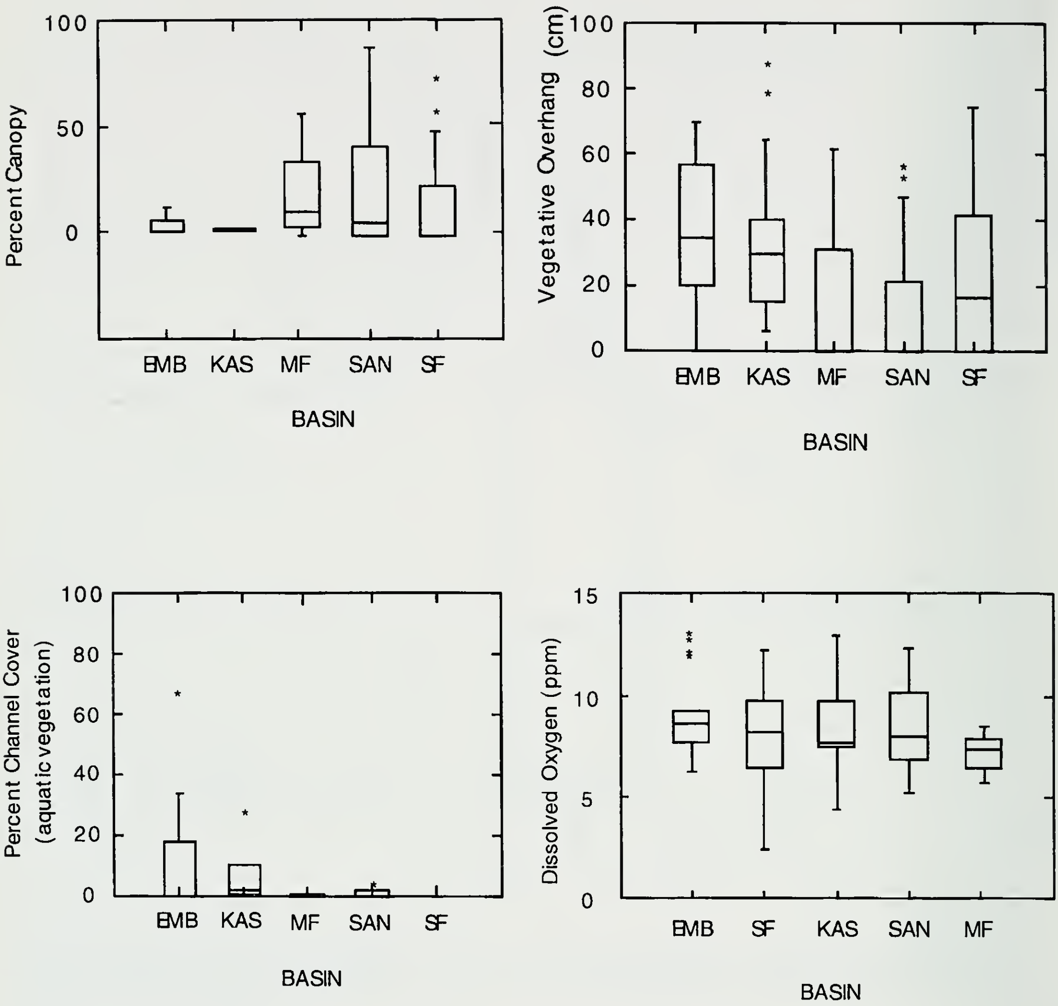
Figure 15



EMB = Embarras River
KAS = Kaskaskia River
MF = Middle Fork River
SAN = Sangamon River
SF = Salt Fork River

Figure 15. Box plots of mean depth, mean compaction (substrate firmness), mean total width, and mean streamside coverage ratings (1=50% with no vegetation, 2=grass or bushes, 3=trees, 4=shrubs) for 1987 sampling stations in the major drainage basins of Champaign County.

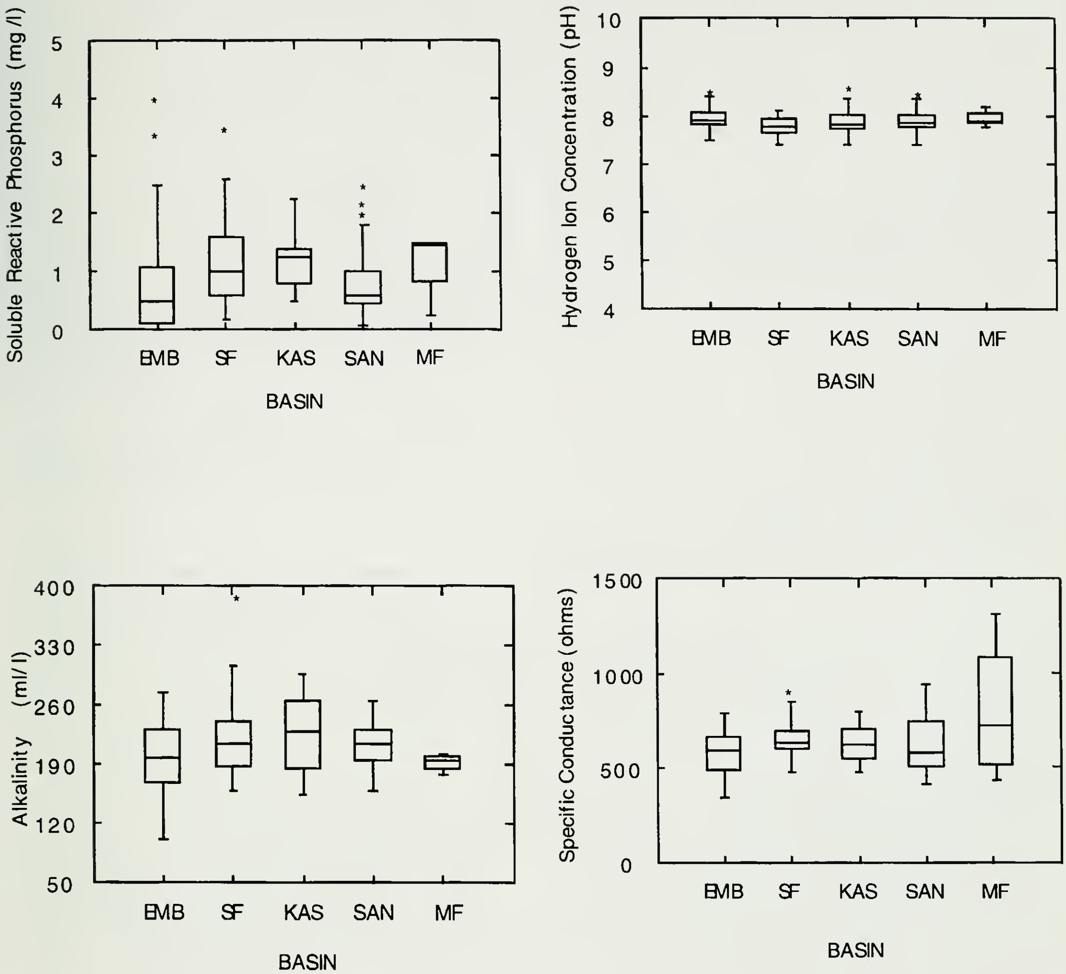
Figure 16



EMB = Embarras River
KAS = Kaskaskia River
MF = Middle Fork River
SAN = Sangamon River
SF = Salt Fork River

Figure 16. Box plots of mean percent canopy (cover over water), mean bank vegetative overhang, percent vegetative cover (aquatic vegetation) of the channel, and mean dissolved oxygen at the 1987 sampling stations in each of the major drainage basins of Champaign County.

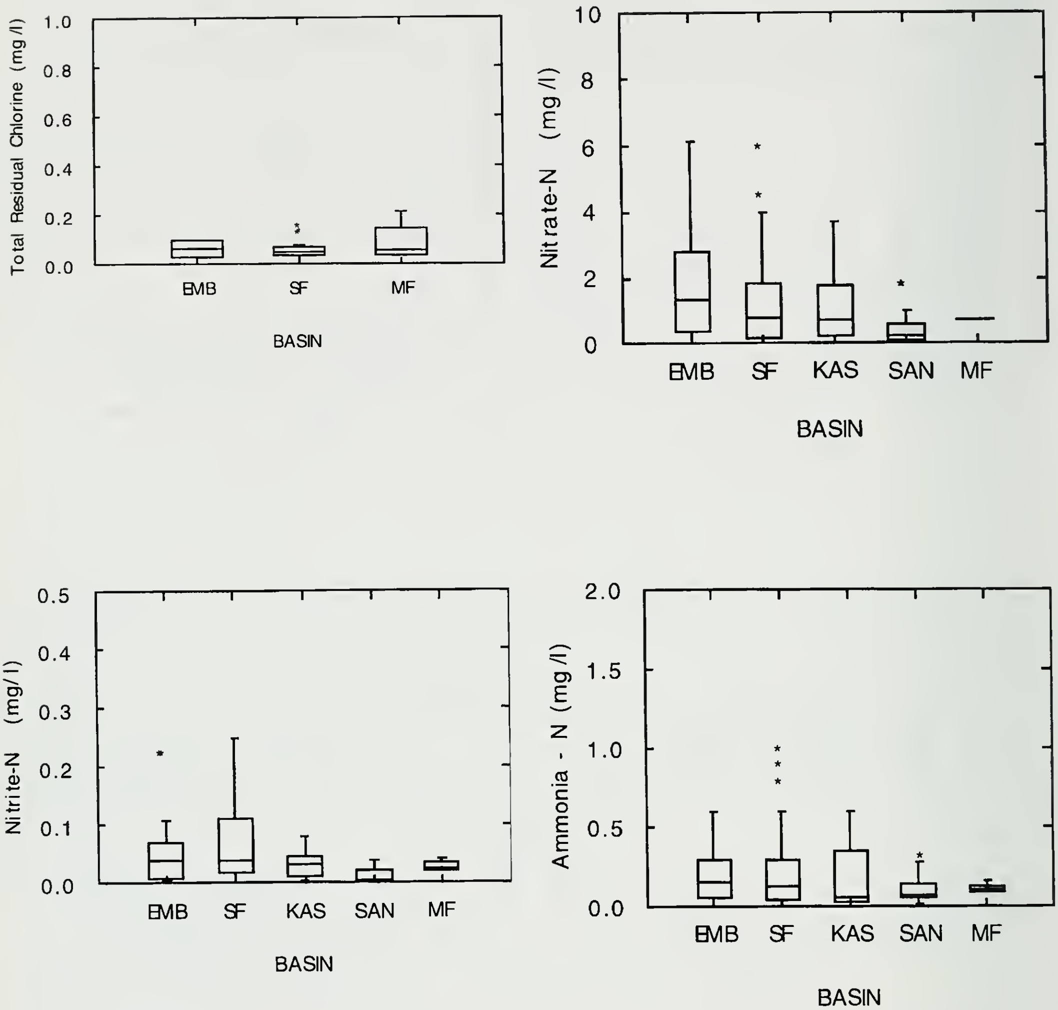
Figure 17



EMB = Embarras River
KAS = Kaskaskia River
MF = Middle Fork River
SAN = Sangamon River
SF = Salt Fork River

Figure 17. Box plots of mean soluble reactive phosphorous, hydrogen ion concentration, alkalinity, and specific conductance at the 1987 sampling stations in the major drainage basins of Champaign County.

Figure 18



EMB = Embarras River
KAS = Kaskaskia River
MF = Middle Fork River
SAN = Sangamon River
SF = Salt Fork River

Figure 18. Box plots of mean total residual chlorine, mean nitrate-N, nitrite-N, and ammonia-N concentrations at the 1987 sampling stations in each of the major drainage basins of Champaign County.

cover ratings displayed little or no variation at stations in the Kaskaskia or Embarras basins (Figure 15), reflecting the channelized nature of most smaller streams in these basins. This lack of variation reflects the early channelization of the prairie drainages and the dominance of row-crop agriculture in the county. A further indication of the influence of agriculture on the streams is the consistently high nutrient concentrations (Figures 17 and 18). This lack of variability is further reflected by the lack of distinct groupings in a cluster analysis based on uncorrelated physical, chemical, and riparian land-use data collected in 1987, prior to the 1988 drought.

FISH COMMUNITY-ENVIRONMENTAL PARAMETER RELATIONSHIP

Methods

To assess the influence of physical and chemical habitat parameters on the fish communities, a matrix of uncorrelated and standardized environmental variables by station was developed. Stations were assigned to one of six groups identified on the basis of a cluster analysis (Wilkinson 1989) that used fish presence-absence data from 101 stations sampled in 1987. A Jaccard similarity coefficient (Gower 1985) was calculated for each pair of stations and the resulting station-by-station matrix was clustered using the complete linkage algorithm and Euclidean distance measures (Wilkinson 1989). A total of 81 taxa of fish collected among the 101 stations was used in developing the presence/absence matrix.

The resulting station groupings (Table 7) were subsequently used to categorize station environmental data using multiple discriminant analysis (MDA; Wilkinson 1989). The purpose of this analysis was to identify those environmental parameters that accounted for the majority of the variance among the six station groups. The initial list of environmental parameters used in the MDA consisted of uncorrelated environmental parameters in four general categories: water chemistry, instream habitat, riparian land use, and basin scale parameters. The water chemistry parameters included ammonia-N, soluble reactive phosphorus, turbidity, and specific conductance. Physical habitat parameters included mean station depth, coefficient of variation in station velocity, percent channel vegetative cover, left and right bank undercut, and percent total shading. Riparian land-use parameters included percent right-bank buffer crop; percent right-bank corn, hay, oats, pasture, soybean, and urban land; and percent left-bank urban land. Basin scale parameters included the total drainage area of the sampling station and the drainage basin affiliation (e.g., Sangamon, Salt Fork, etc.).

Preliminary analyses indicated that six of the riparian land-use parameters (hay, oats, pasture, soybeans, urban land, and left-bank urban land) were not significantly different across station groupings in univariate analyses; therefore, these parameters were eliminated from the final MDA.

Station Groupings

Six station groups resulted from the cluster analysis of the fish presence-absence data (Table 7). Examination of the basin affiliation of stations within individual clusters revealed that the six station groupings did not clearly correspond to particular drainage basins. All station groupings consisted of stations from at least three drainage basins except Group 4, which contained only two stations, each from a different drainage basin. Group 1 was dominated by Salt Fork River and Embarras River stations. Group 2 was dominated by Salt Fork River, Sangamon River, and Embarras River stations; Group 3 by Kaskaskia River, and secondarily by Salt Fork River and Sangamon River stations. Group 5 was dominated by Sangamon River and Kaskaskia River stations, and Group 6 by Sangamon River stations.

Group 2 was the largest group, containing 45% of the total number of stations. Average fish species richness at Group 2 stations was 15.2 ± 3.8 SD and ranged from 9 to 27 species. This large number of stations from a wide array of drainage basins as well as stream sizes categorized into a single group reflects the general similarity in fish communities within the county. Group 6 had the highest average

Table 7. Distribution by drainage basin of stations in six groups established by cluster analysis of presence or absence of fish species. Some associated habitat characteristics are given. See footnote for abbreviations.

	Station Groups					
	1	2	3	4	5	6
Number of stations	12	42	14	2	10	21
Numbers by basin	SF 6 EMB 5 KAS 1	SF 19 SAN 12 EMB 9 KAS 2	KAS 6 SF 4 SAN 4	KAS 1 SF 1	KAS 3 SAN 3 SF 2 EMB 1 LV 1	SAN 10 EMB 4 MF 4 SF 3
Mean species richness	7.4	15.2	12.4	6.5	10.9	19.2
General stream size	small	mid/large	small	small/mid	mid	mid/large
Probable discriminant parameters	Low mean depth	High SRP Low shading	Low SRP High shading			High mean depth Mature floodplai

Abbreviations: SF = Salt Fork, MF = Middle Fork, EMB = Embarras, SAN = Sangamon, LV = Little Vermilion, KAS = Kaskaskia, SRP = Soluble Reactive Phosphorus.

species richness (19.2 ± 5.6 SD) probably because it was largely composed of mid- to large-river stations. Groups 1 and 3 generally consisted of small streams but had substantially different species richness means. Stations in Group 1 averaged only 7.4 taxa per station while those in Group 3 averaged 12.4 taxa. This difference in average species richness among these similar-sized streams suggests that communities at stations in Group 1 were more stressed, usually below a water-quality change, than were communities at stations composing Group 3. Group 5 consisted largely of mid-size streams and averaged 10.9 ± 3.1 SD species. Group 4 consisted of only two stations, and averaged only 6.5 species per station (range 6-7). One of the two stations in Group 4 located in the upper Salt Fork basin near Urbana differed from all other stations of that size due to an extensively deep undercut bank as the small stream passed along the edge of Yankee Ridge moraine. The separate categorization of these two stations from other stations suggests that their fish communities were unique for some undetermined reason.

Environmental Discriminant Functions

All multivariate tests were significant at $\propto=0.05$ when the 14 uncorrelated environmental parameters were included in MDA. Because we used only stations without missing values in our MDA procedures, only 84 of the original 101 sampling stations belonging to the six station clusters were incorporated in the development of the final five discriminant functions (Table 8). Of these stations, MDA properly categorized 73% of the Group 1 stations, 45% of the Group 2 stations, 58% of the Group 3 stations, 100% of the Group 4 stations, 71% of the Group 5 stations, and 80% of the Group 6 stations. Given that these are species presence-absence data and the sampling stations are subject to multiple stresses, such ranges in station categorizations are quite reasonable.

Each discriminant function (DF) is composed of all of the uncorrelated environmental variables entered into the analysis. The degree to which each environmental variable influences a DF is reflected in the magnitude (either positive or negative association) of the standardized coefficient scores. The environmental variables with the highest absolute coefficients are the variables that have the greatest influence on a single DF axis. For instance, a group of stations separated from other station groups along the DF 1 axis would be distinguished from one another on the basis of specific conductance, depth, and drainage area. The most influential environmental variables comprising each of the five generated DFs are reported in Table 8.

Insights into the environmental parameters responsible for the classification of stations with similar fish communities into separate groups can be obtained by plotting the standardized coefficients of the environmental variables from each station (letters designating their group affiliation; a=Group 1, b=Group 2, etc.) along pairs of DF axes (e.g., Figure 19). When the stations were plotted in relation to DF 1 and DF 2 axes, the stations composing Group 6 (f in Figure 19) were more distant from the other stations. The Group 6 (f) stations had lower DF 1 coefficients and slightly higher DF 2 coefficients. Table 8 indicates that the DF 1 axis was largely influenced by specific conductance, drainage area, and mean depth. The DF 2 axis was composed of drainage area, proportion of buffer crop, and soluble reactive phosphorus concentration. The stations in Group 6 had the highest mean specific conductance, a high mean depth, and the largest drainage areas. These factors are characteristic of larger river systems. Thus, these results indicate that the assemblage of fishes at stations in Group 6 (Table 7) differed from the assemblages at other stations and that the difference was largely attributable to a larger river environment. These systems had higher mean depth and broader floodplains, thereby accounting for the negative association with buffer crops.

Group 2, the largest cluster of stations, was moderately distinguishable from other station groups on the basis of higher SRP concentrations, fairly low total shading, and a greater degree of undercut banks. Discrimination of Group 3 from other station groups was apparent along axes DF 3 and DF 4. Stations in

Table 8. Principal environmental variables associated with each discriminant function (DF) and their associated standardized coefficients. R.B. = Right bank.

DF 1	Standardized Coefficient
Specific conductance	0.669
Mean depth	-0.398
Drainage area	0.275

DF 2	Standardized Coefficient
Drainage area	-0.941
% R.B. buffer cover crop	0.514
Soluble reactive phosphorus	0.469

DF 3	Standardized Coefficient
Basin	-1.220
Mean depth	-0.673
Total shade	0.666

DF 4	Standardized Coefficient
R.B. undercut	0.618
Total shade	-0.524
Soluble reactive phosphorus	0.441

DF 5	Standardized Coefficient
Specific conductance	-1.143
Turbidity	1.039
% R.B. corn crop	0.665

this group were characterized by relatively high total shading, low mean depth, and low SRP concentrations. Much of the total shading, however, appears to be associated with the steep, channelized banks as opposed to the development of riparian vegetation. Also, the majority of these stations occurred in either the Embarras or the Salt Fork drainage. Although the mean depth was fairly low among the Group 3 stations (11.9 cm), it was even lower among the Group 1 stations (8.3 cm). These data suggest that the higher mean species richness at stations comprising Group 3 relative to those at the similarly sized Group 1 stations may be associated with the differences in depth because few other environmental factors varied.

Implications for Watershed Management

Overall, these results suggest that stream size, mean depth, total shading, percent riparian buffer cover, and nutrient concentrations are associated with the major differences in stream fish communities among sampling stations in Champaign County. From a management perspective, little can be done to control or influence factors associated with stream size. The unstable and persistently shifting substrata, in association with the high sediment loads in the region, will make it difficult to alter channel depth. Providing for the development of a natural sinuosity as opposed to maintenance of channelized conditions could, however, permit development of deeper pools along stream channels. High nutrient concentrations result in increased rates of primary production and diel fluctuations in dissolved oxygen concentrations in midwestern streams (Wiley et al. 1990), which can adversely impact stream fish communities. Control of stream nutrient concentrations requires both reductions in inputs from the watershed and implementation of corridor and/or riparian mitigation control strategies (Osborne and Herricks 1989; Osborne and Kovacic 1993), both of which can be achieved through reasonable watershed management programs. Finally, incorporation of buffer vegetation to reduce surface and subsurface inputs of nutrients to streams (Osborne 1989; Kovacic et al. 1990) and planting of vegetation to increase stream shading would reduce instream primary production (Wiley et al. 1990). These data suggest the structure of stream fish communities can be protected, at least to a moderate extent, by resource managers through manipulation of key environmental variables, such as total shading, riparian buffer strips of cover crops, alterations in nutrient inputs, and modification of channel depths by allowing sinuosity to develop.

Figure 19

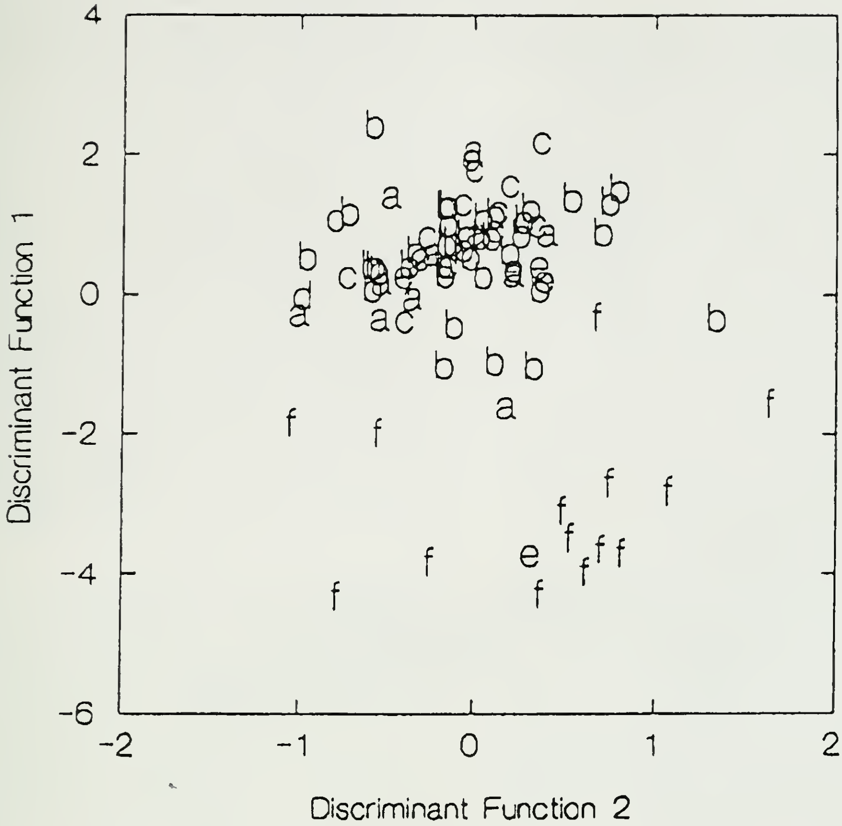


Figure 19. Station groups generated using cluster analysis (see text for details) plotted in discriminant space with respect to DF1 and DF2.

Letters represent station group number:

a = Group 1
b = Group 2
c = Group 3
d = Group 4
e = Group 5
f = Group 6

FISH DISTRIBUTION AS AFFECTED BY POLLUTION

Pollution in Champaign County has been most severe in areas of dense populations and industrial development, that is, within Champaign-Urbana. Types of pollution have changed considerably during the years spanned by the four surveys of Champaign County fishes. Organic pollution, which began before the period of the backyard privy, still exists today, even with our modern scientific treatment of domestic wastes. Many sources of chemical pollution have appeared and some of these continue to threaten aquatic life.

At the time Forbes and Richardson made their collections, 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 Saline Branch proper. Additional pollution came from stables, a power plant, and a few small industries. By 1918, Boneyard Creek was apparently barren of clean-water organisms (Baker 1922).

The Saline Branch of the Salt Fork River, called the West Branch by Thompson and Hunt and by Larimore and Smith, from Urbana to St. Joseph was described by Baker (1922) as laden with masses of decomposing matter made up of foul-water algae and protozoa, and its bottom was inhabited by slime worms.

During these early years of urban growth, the University of Illinois was a leader in sanitary engineering. In 1897, Professor A.N. Talbot designed one of the first septic tanks and saw it built at the present site of the treatment plant in Urbana. From 1913 to 1916, Dr. Edward Bartow and Associates experimented at this plant with a new activated sludge process. In 1917, legislation permitted the organization of the Urbana-Champaign Sanitary District. By 1924, sewage from both cities passed through a new disposal plant before entering the Saline Branch. Although the disposal plant was state-of-the-art, a high level of pollution still existed in the Saline Branch. Improvements in the efficiency and treatment process of the sanitary system were made at frequent intervals up to the present, especially in the 1980s with the reduction of ammonia and elimination of chlorination. During the 1950s, Rantoul, Gibson City, and Chanute Air Force Base also installed sewage treatment plants.

In the past 90 years, Champaign County has improved its sewer systems and eliminated many sources of pollutants, such as the early gas plants and stables, and wastes from canning plants, milk plants, and soybean mills. The county, however, still must contend with chemical spills, oils and salts that wash from roads, and agricultural chemicals, such as modern fertilizers, herbicides, and insecticides. The University of Illinois chemical laboratories and an ever-increasing number of industries also threaten with chemical spills.

The increasing volume of effluent was a growing problem. Now the ammonia and chlorine that had been chronic problems have been eliminated (Karr et al. 1985); however, the enormous increase in flow through the plant, resulting from the growth of Champaign-Urbana, benefits the Saline Branch by increasing its volume and augmenting low flows with waters from an underground aquifer.

Areas of Chronic Pollution

Larimore and Smith (1963) discussed seven principal areas of chronic pollution (Figure 20) that had severely affected the distribution of Champaign County fishes (see distribution maps in Appendix 2). The following update of conditions in these seven areas illustrates the water quality improvements made since the passage of the Water Pollution Control Act of 1966, the Federal Water Pollution Control Act Amendment of 1972, the Clean Water Act of 1972, improvements in treatment of municipal wastes, and better understanding of industrial and agricultural chemicals.

Boneyard Creek. Because of its location in the center of Champaign-Urbana (Figure 20), Boneyard Creek received quantities of various pollutants during the first half of this century. Although Forbes and Richardson collected johnny darters from the stream, pollution existed even at that time. According to Baker (1922), Boneyard Creek was receiving domestic pollutants in 1915 as well as oil and tar from the gas works. Thompson and Hunt (1930) stated that Boneyard Creek 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. Although no fish samples were taken from Boneyard Creek during the recent survey, schools of fish are often present upstream

(Continued on page 98)

Figure 20

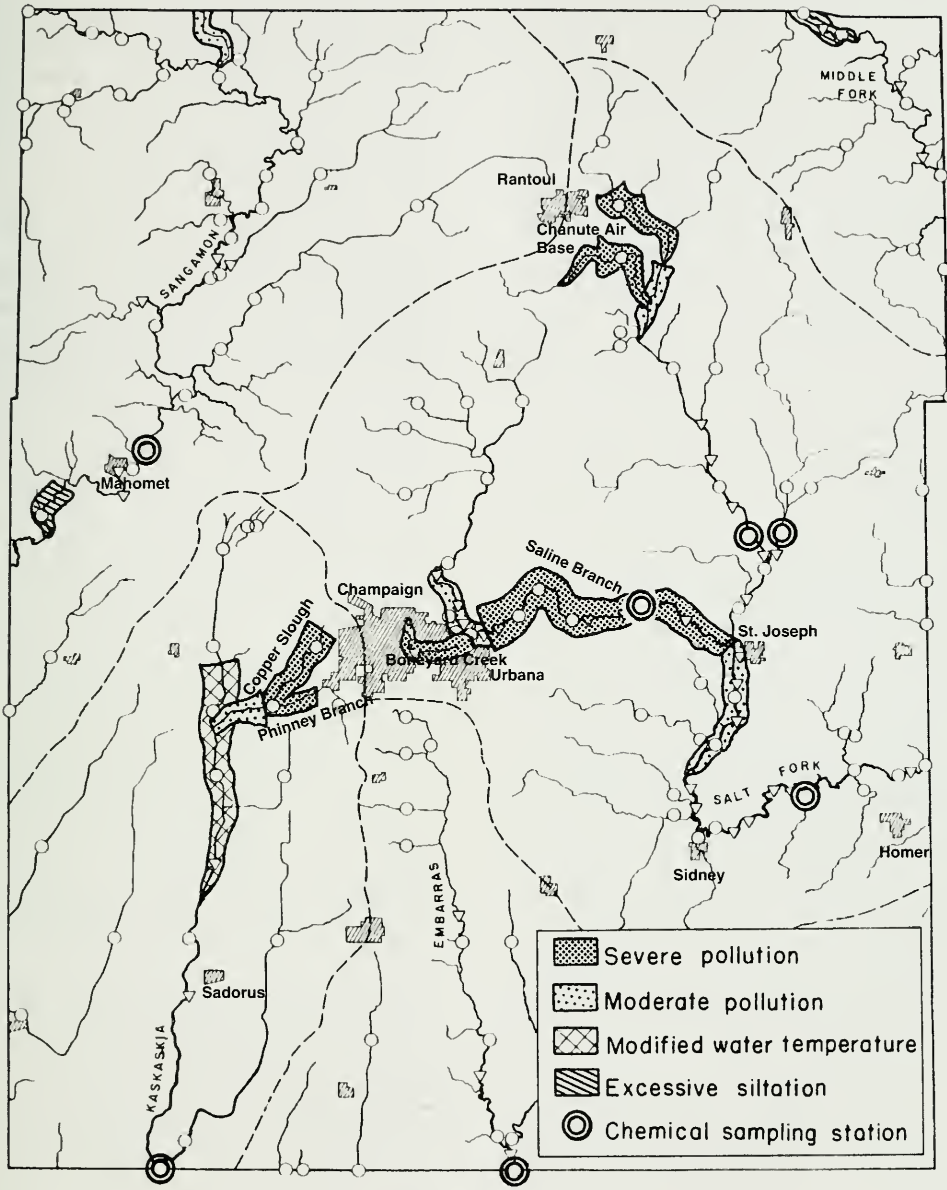


Figure 20. Distribution of pollution in Champaign County and location of seven stations at which chemical analyses were made in 1960 (from Larimore and Smith 1963).

through Urbana, even during periods of moderate flow. They continue to be threatened by accidental spills from the university, small streamside businesses, and wash from parking lots.

Saline Branch of the Salt Fork River. This small stream (Figure 20), draining the marshes and swales north of Urbana, was ditched with the establishment of the Wildcat Slough Drainage District in 1870 (Hay and Stall 1974). Thus, most of the tallgrass prairie habitat had been lost before Forbes and Richardson sampled the straight Saline Ditch. Although Forbes and Richardson found a variety of fishes in the Saline Branch during their survey, this creek subsequently underwent drastic reduction in number of species.

Larimore and Smith (1963) divided the Saline Branch into three sections: Section 1, the 7 miles of creek above the Champaign-Urbana disposal plant; Section 2, the 10 miles from the disposal plant to its junction with the Salt Fork; and Section 3, the stream (actually the Salt Fork) from the junction downstream for a distance of 2 miles. Table 9 shows the numbers of species taken at each station through these three sections, with the last station listed representing Section 3.

Section 1 presumably was relatively free of pollution when Forbes and Richardson collected at least 23 species there. In 1928 Thompson and Hunt (1930) 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 polluted this portion of the stream. In 1959 Larimore and Smith found only 15 species; in 1987 we collected 19 species through this section.

Examples of species that disappeared early from this section were the spotted sucker, golden redhorse, suckermouth minnow, black bullhead, black crappie, greenside darter, and blackside darter. Species that disappeared as pollution increased were the grass pickerel, tadpole madtom, brook silverside, and bluegill. Examples of the most common species appearing in the section for the first time after 1900 were the carp, striped shiner, hornyhead chub, creek chub, and redfin shiner, taken by Thompson and Hunt.

The Saline Branch below the disposal plant, Section 2, was already polluted by Boneyard Creek and the inadequate waste treatment plant at the time of the first survey. Pollution, however, apparently had not greatly reduced the number of species present, because Forbes and Richardson reported 33 species in the area. Soon after, however, water conditions became intolerable to most fishes (Baker 1922). When Thompson and Hunt collected in this 10-mile stretch, they found 7 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, Larimore and Smith found only three species and a total of 10 individuals. However, numerous revisits to these stations during the following spring and early summer enabled them to collect a few individuals of 12 other species. Many more species disappeared from Section 2 than from Section 1. Species appearing for the first time in Section 2 after the advent of pollution include the carp and redfin shiner. In 1987, we collected many individuals of 17 species.

Section 3 (actually the Salt Fork), a 2-mile stretch directly below the confluence of the two branches, receives the benefit of dilution from the cleaner branch draining from the north. Twelve species of fish were collected in this section during the first survey, 15 in the second, 12 in the third, and 15 in the fourth (Table 9). Signs of pollution were apparent in this section during the third survey, especially at times of low water. Upstream improvement in water quality resulted in more species (15) being taken (Table 9) in the most recent survey.

Upper Salt Fork River. The main stem of the upper Salt Fork, called the East Branch by Larimore and Smith (1963), has been polluted by the city of Rantoul and by Chanute Air Force Base. At the time of the Thompson and Hunt survey, collections made near the outlet of the Rantoul sewer ditch during warm weather contained an abundance of 12 species; however, no fish were found at this location during the cool periods of the year. Larimore and Smith found this location polluted by effluent from a disposal plant in operation since 1954. In August 1959, the stream below the plant was foul and the bottom was covered with sludge. It contained a few fishes that were observed but not identified. The treatment plant was improved, and 16 species were collected in the recent survey.

Chanute Air Force Base near Rantoul operated three treatment plants that polluted a small stream flowing eastward from the southern edge of the base. Before the base had been expanded in the 1940s, a station on this small stream contained abundant populations of 14 species at the time of the Thompson and Hunt survey, but yielded only three creek chubs and a carp when Larimore and Smith collected there in August 1959. Fourteen species were collected during the recent survey.

The influence of pollution extended downstream several miles when Larimore and Smith collected. Two and one-half miles below the Rantoul disposal plant, the stream smelled foul and contained other evidence of sewage in October 1959, when few specimens of six species were taken. Two miles below that, in the mouth of the small creek that flows from the air base into the Salt Fork, fairly large numbers of fish were taken during the same month, suggesting that the organic waste from Rantoul had been digested and diluted. Although this station was not visited in the recent survey, a station 3 miles downstream contained 19 species.

Lower Salt Fork River. Thompson and Hunt considered the lower Salt Fork severely affected by pollution as far downstream as Homer Dam, a low-head plank dam that remained partially intact up to the time of Larimore and Smith. They collected only a small variety of species and found low population numbers at the stations in this area. In 1959 septic conditions occurred between St. Joseph and Sidney. Between Sidney and the county line, however, the stream appeared clear of pollution, although the water chemistry still reflected the upstream pollution. Several times during the early winters of the 1960s, when the water was without ice cover, nutrient loading from Champaign-Urbana produced dense blooms of plankton and periphyton (mostly diatoms and *Euglena*). Stressed and dead fish could be seen from St. Joseph downstream into Vermilion County. Such conditions were not seen during the 1970s and 1980s, possibly because of the increased use of herbicides affecting instream plant growth.

In the two most recent surveys, including the period of nutrient enrichment just mentioned, a variety of fishes was taken below St. Joseph (Table 9) and at four stations between Sidney and Homer. Fewer species were taken at those lower stations in the recent survey than by Larimore and Smith, although 2 years earlier, Day (1988), with the Illinois Department of Conservation, procured more species, reflecting his more extensive collecting in that reach. At a station near Homer where Larimore and Smith took 22 species and Larimore and Bayley took 18, Day took 26 species. At this time we do not know the effects of sedimentation or of herbicides that are applied to virtually every acre of cultivated land in the watershed.

Copper Slough, Phinney Branch. Both branches of the small stream (see Figure 20) draining the west edge of Champaign apparently were already polluted by 1928; Thompson and Hunt found no fish at their one station near Illinois State Route 10. In 1959, Copper Slough, the north branch, received industrial and domestic waste. Only the blackstripe topminnow was taken in Copper Slough by Larimore and Smith. At that time, Phinney Branch, the east branch, was receiving 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 when Larimore and Smith sampled. At the junction of Phinney Branch and Copper Slough, 20 species of fishes, including large numbers of red shiners and striped shiners, were collected during the 1959 survey. On February 27, 1960, however, 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 allowed the survival of fishes in the lower reaches only during certain times of the year. The small treatment plant on Phinney Branch was improved in 1968 and produced a noticeable improvement in water quality.

Although the recent survey did not include fish samples from either branch, 15 species were taken at their confluence. However, the following summer an ammonium spill killed the fish and most of the invertebrates in Copper Slough and down the Kaskaskia River to Sadorus. As part of the required mitigation, the stream was stocked with largemouth bass, smallmouth bass, channel catfish, and fathead minnows, and a recovery study was conducted. We have not seen a report of this study, but we know that the fish population recovered the following year. Soon after that, Hoglund (1991) collected 33 species at the confluence of these branches and the Kaskaskia River.

Table 9. Number of species taken at sampling stations above and below sewage disposal plant on Saline Branch of th Salt Fork by Forbes and Richardson, Thompson and Hunt, Larimore and Smith, and Larimore and Bayley. The last station is 2 miles below confluence of the Saline Branch and the Salt Fork near St. Joseph. NC = no collection.

Station in relation to Disposal Plant	Forbes & Richardson Number of species	Thompson & Hunt Number of species	Larimore & Smith Number of species	Larimore & Bayley Number of species
7 miles above	NC	10	6	13
4 miles above	18	10	13	13
1 mile above	NC	11	10	14
1/2 mile above	10	11	9	13
1 1/4 miles below	3	2	0	8
2 1/4 miles below	NC	3	1	12
4 miles below	18	2	2	16
6 1/4 miles below	24	4	1	17
12 miles below	12	15	12	15

Upper Sangamon River. Domestic wastes from Gibson City (see Figure 20) and wastes from a packing plant and a soybean mill caused fish kills in Drummer Creek and the upper Sangamon almost annually through the 1960s. According to Thompson and Hunt, wastes from a canning factory at Gibson City had caused the fish kill they described. Such kills have extended downstream as far as Mahomet. The threat of severe pollution was reduced, but not eliminated, by the installation of a disposal plant at Gibson City for the treatment of domestic wastes. With additional restrictions in point-source pollution during the 1970s, serious fish kills have occurred only infrequently in the upper Sangamon. The recent survey collected 15 species in the lower reaches of Drummer Creek. The following year, however, fish were killed in the upper reaches of that small stream by discharge from the soybean mill in Gibson City. Big Ditch in the upper Sangamon basin receives municipal wastes from Rantoul that affect the immediate reach, but Schlosser and Karr (1981) and Angermeier and Schlosser (1987) collected 33 species from that third-order stream during the 1970s.

Upper Kaskaskia River. Alteration of the natural water temperatures of a stream may be considered a type of pollution. Beginning in the late 1950s, the U.S. Industrial Chemical Company from time to time pumped large volumes of water from three wells into the Kaskaskia west of Champaign (Figure 20) for use at its plants 20 miles downstream. The temperature of the well water was near 55°F. On July 14, 1959, at 3:00 P.M., when Larimore and Smith collected, the stream temperature above these wells was 91°F, at the wells 60°F, and the water temperature remained subnormal for 5 miles below the wells. They collected only two species above the pumps and seven below. Large aggregations of fish and heavy algal blooms occurred in the 2 miles of stream below the wells. Pumping was discontinued after a few years. In the recent survey, 20 species were taken above where the pumps had been and 15 below. This change suggests the cold water had been a barrier to the headwater fishes, cooling the stream water more than 30°F in the summer and warming it 15°F in the winter.

REVIEW OF ENVIRONMENTAL INFLUENCES

During the past 150 years, the Grand Prairie has been dredged, drained, and developed into the highly organized Champaign County. The human-induced modifications have been made with little concern for long-term environmental effects. With no early foresight, modifications by humans have been both good and bad for a sustainable system.

Influences and Status

Draining and dredging. Although some dredging and draining had been carried out during the two decades before the Drainage Act of 1879, the Act permitted farmers to organize to drain large parts of a basin and to pay for the work with a regular tax assessment (Hay and Stall 1974). Draining the swales and marshes and channelizing the streams (Figures 2 and 3) established very productive farmland, but permanently changed or eliminated much of the fish habitat. Habitat diversity was severely reduced in those streams with only modest possibilities of some recovery, especially if the channelized areas were to be maintained as perfectly tailored ditches (Figure 21).

Cattle and cattle feedlots. Before the prairie grasslands were drained, raising cattle was only possible on well-drained land along the larger streams and moraines. Cattle production increased as grains were produced. The fattened cattle were taken to the rapidly expanding Chicago stockyards, usually on the new Illinois Central Railroad. These cattle grazed, waded, and watered along the streams (Figure 22), causing severe bank damage and increased turbidity. Rich, manure-laden runoff from cattle feedlots damaged nearby streams.

About the time of the Larimore and Smith survey in 1959, the cattle business of the county started to decline. Few farmers currently continue to fatten cattle, and these usually in feedlots, so that the grazing of stream banks has been greatly reduced (Figure 22). Large feedlots are required to have oxidation ponds to control their runoff. Such oxidation ponds, however, are a threat to nearby streams because they frequently overflow or rupture, killing fish in the receiving streams.

Soil erosion. Very little soil moved off the Grand Prairie, but when land was drained and the grasses were replaced by corn grown in rows, wind and rain immediately started moving the soils down the gentle moraine slopes and the exposed loess of dry grain fields. Row crops were planted without considering the slope of the fields, grass waterways were not established, and timber was cleared, exacerbating wind erosion. At the turn of the century (Forbes and Richardson time) the Osage orange tree was brought in for "living fences." Rows of these trees reduced wind erosion until they were mostly removed in the 1960s.

Near the middle of this century grass waterways and contour farming were being promoted, and some sloping fields were terraced. Not until passage of the 1985 Farm Bill, however, were farmers given some financial incentives to quit cultivating highly erodable fields and put them into cover crops. This Conservation Reserve Program later encouraged protection of wetlands and riparian filter strips. Many farmers in Champaign County now follow conservation tilling of their grain fields, only cutting the soil surface and leaving it covered with organic litter. There is now less fall plowing, which in the past increased wind and rain erosion in winter.

These conservation practices have reduced the loss of topsoil, but even in the flat to sloping fields of Champaign County wind and rain still transport great amounts of silt into our streams. Excessive siltation is still considered the most important detrimental influence on our Illinois stream fishes (Smith 1971) because it suppresses benthic organisms, fish food production, and reproduction of some fishes.

Pollution. Abatement of point-source pollution has been one of the county's greatest environmental successes since the first survey of fishes by Forbes and Richardson at the turn of the century. Extensive development of pollution, mostly municipal waste from the rapidly increasing urban population, and the successful reduction of pollution effects following passage of the Clean Water Act of 1972 and other legislation was discussed in a previous section of this report.

Municipal and industrial wastes. For many years, state and federal laws have aimed to regulate point-source pollution. Stronger restrictions and active enforcement of the Clean

(Continued on page 104)

Figure 21

The Salt Fork below St. Joseph received moderate maintenance since being dredged in 1930. This photograph was taken in November 1994.

Same view as above showing maintenance in January 1995 without proper permit.

Maintenance nearly complete. After first high water, stream bed returned to predredged condition of sandy bed load but with none of the previous bars or shallow pools. Bank cover and instream habitat were severely reduced.

Figure 22

At the time of the third survey, many cattle waded the streams of Champaign County, causing severe bank erosion.

With moderate grazing, bank vegetation was reduced but banks remained stable in most areas.

Same stream as above after 20 years with no grazing. Notice lush bank cover.

Water Act of 1972 brought about real progress toward cleaner streams. Although many streams across the U.S. are still chemically degraded, those in Champaign County are not, especially when compared to their condition during the Larimore and Smith survey. The recent removal of chlorine and the reduction of ammonia in most municipal effluents have been a great benefit to stream fishes, and may account for the improvement of several species listed in the fish assemblage analysis.

Animal wastes. See discussion of "Cattle and Cattle Feedlots" on page 101.

Fertilizers and pesticides. These nonpoint pollutants increased rapidly between the third and recent surveys. Although several insecticides have been banned, others are used on almost all field crops. Many new selective herbicides are applied to every crop except wheat. No direct effects of herbicides on stream fish have been identified, especially joint (synergistic) effects with other chemicals.

Chemical spills. The frequency of accidental chemical introduction to county streams has decreased in recent years with the better understanding of chemical toxicity and handling. Accidents and carelessness, however, continue to cause severe kills of stream fish even though fines are usually imposed.

Non-native fishes. Names of non-native fishes brought into Champaign County that have not become established in the streams are listed in Table 1 and the "Annotated List of Fishes" (Appendix 1). Only the common carp is established in the local streams but no specific detrimental effects have been identified. Goldfish are occasionally taken.

Dutch elm disease. The American elm was one of the largest, most common trees along Champaign County streams until, in the 1950s, Dutch elm disease killed virtually every one. The dead trees added enormous amounts of woody detritus to the streams that provided fish cover, deflected currents, and formed log jams. The river canopy was temporarily opened. Large American elms are still absent from this area; their place along streams has been filled mostly by silver maple, sycamore, and hackberry.

Urbanization. Urban growth generally means losses of agricultural land and increased municipal waste. In Champaign County, another major influence has been the reduction of the water-storage capacity of the area and an accompanying rapid runoff, exacerbating downstream flooding and low flows. New business and residential developments are being encouraged to include floodwater storage.

Reinvasion of beavers. Soon after the Larimore and Smith survey, beavers, which once had been extirpated from Illinois, began showing up in county ditches and along the larger streams. Beaver dams in ditches and small streams provided new fish habitat and water storage, but increased local flooding and bank erosion. Bank dens on larger streams created new but more limited fish habitat.

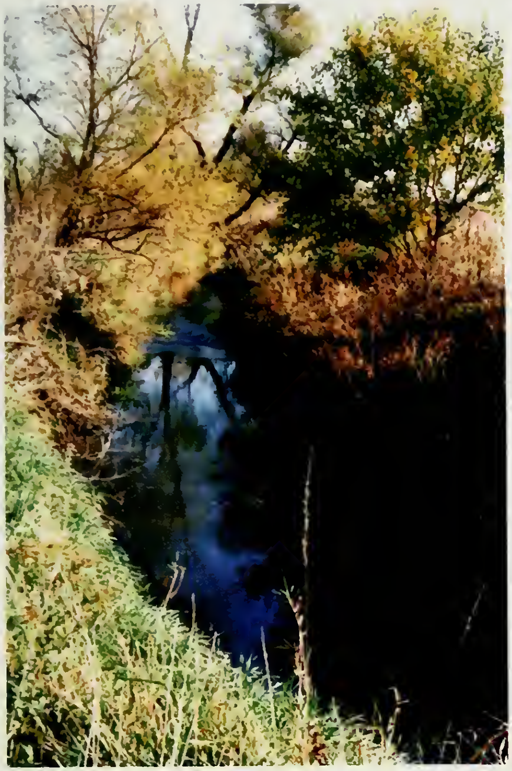
Conclusions of Environmental Influences

1. Habitat diversity has been drastically reduced in our streams. Limiting channel maintenance and restoring water storage on the floodplain would reduce impacts of channelization (Figure 23).

2. The rate of sedimentation has been slowed but silt remains the primary physical factor affecting fish and other aquatic organisms.

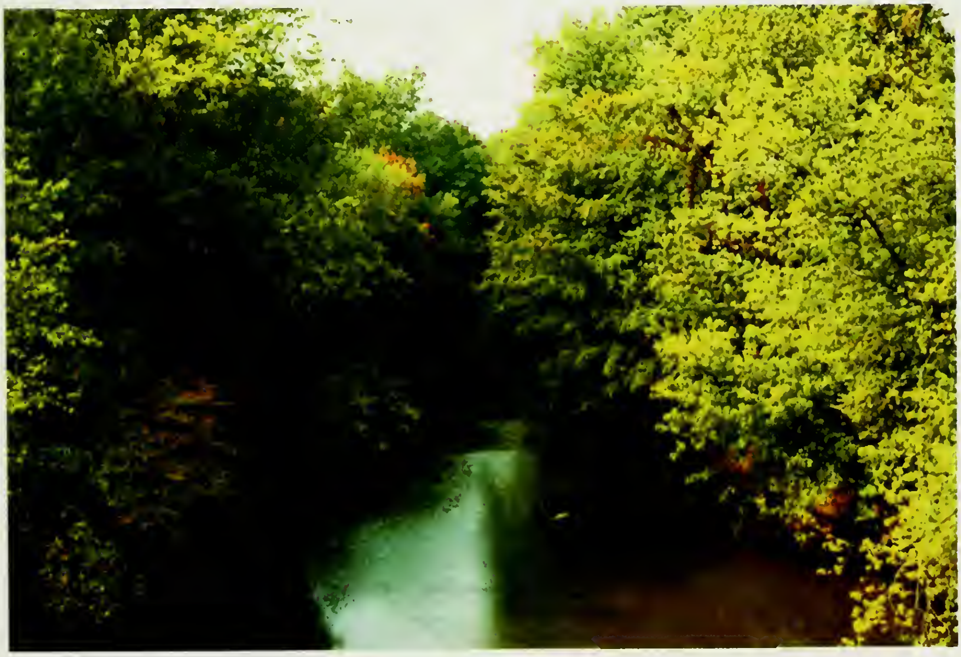
3. Municipal and industrial pollution have been reduced and water quality restored to all areas that had been degraded by chronic pollution. Accidental chemical spills and agricultural fertilizers and pesticides remain primary threats to stream fishes.

Figure 23



Dragline recently went along this dredged stream but removed only obstructions to channel flow.

Very limited maintenance has preserved instream habitat.



Woody vegetation has been permitted to grow on this dredged stream.

SUMMARY

1. Much of Champaign County has been converted from marsh and tallgrass prairie to well-drained fertile farmland. Its streams were modified by dredging, tiling, silting, and other influences that accompanied agriculture.

2. Stream fishes in the six drainage basins of the county were sampled in the same locations in the late 1890s, 1928, 1959-60, and 1987-88. Ninety-two species were recorded in the county during these four surveys. Eighteen species previously recorded were not collected in the recent survey. Of these 18, 16 were never common in the county and 6 are listed as Illinois endangered species. With species disappearing and new ones occurring, the total number of species collected in the most recent three (of four) surveys has remained virtually the same—73, 73, 74.

3. Based upon data from the last three surveys, tests of association and time trends indicated that 12 taxa (species or species complexes that occurred in five or more samples from two or more surveys) in a subset of 47 taxa generally increased in percentage of occurrence, while 5 taxa decreased. Ten taxa showed more complex changes and the remaining 20 taxa showed no significant association or trend. Mean species richness per sample, after correcting for gear efficiency differences, dropped drastically between 1928 and 1959 during the time that water quality deteriorated rapidly.

4. Biomass of large predatory species (mostly sportfishes) increased during the past 30 years but in the county the physical habitat apparently limits the distribution and abundance of most of these species.

5. Urban spread has taken much agricultural land and reduced water retention in the floodplains, while the reduction of cattle grazing and the use of conservation tillage have improved the streams.

6. Habitat parameters varied little among most sites. However, fish communities were distinguishable on the basis of discriminant functions related to river size that were influenced primarily by mean depth, drainage area, and specific conductance, and secondarily by riparian crops and soluble reactive phosphorous.

7. Historical evidence indicates that poor water quality was a major limiting factor for most fishes in Champaign County in the 1950s. Results from the recent survey indicate that water quality has been greatly improved during the past 30 years with the elimination of chronic pollution in seven principal areas.

8. The limiting physical habitat is still a function of land-use practices associated with agriculture, particularly channelization and channel maintenance for drainage. Although the dredged streams may never be allowed to regain the diversity of habitat that existed before channelization, some farmers and drainage engineers are limiting channel maintenance and permitting the development of instream meanders, bars, pools, and bank vegetation. Most of the fishes of Champaign County quickly respond to these habitat improvements.

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APPENDIX 1 ANNOTATED LIST OF FISHES

Ninety-two species are included in our annotated list of the fishes of Champaign County. A few other species not in the annotated list are known from streams in adjacent counties and may eventually be found in this county. For example, *Moxostoma carinatum* (Cope), *Stizostedion canadense* (Smith), and *Etheostoma camurum* (Cope) have been collected a short distance downstream from the county border in the Salt Fork; *Nocomis micropogon* in the Little Vermilion in adjacent Vermilion County; and *Campostoma oligolepis* Hubbs & Greene in neighboring counties of the Kaskaskia River drainage. A few other species, such as *Anguilla rostrata* (Lesueur), reported by Champaign County fishermen but not examined by us or documented by specimens, have not been included in our list.

The following species have been released in Champaign County lakes and ponds but have been taken only once in the streams or not at all:

1. *Amia calva* Linnaeus, bowfin
2. *Ctenopharyngodon idella* (Valenciennes), grass carp (diploid and triploid)
3. *Ameiurus catus* (Linnaeus), white catfish
4. *Ameiurus nebulosus* (Lesueur), brown bullhead
5. *Ictalurus furcatus* (Lesueur), blue catfish
6. *Esox masquinongy* Mitchill, muskellunge
7. *Esox lucius* Linnaeus hybrid with above species, tiger muskie
8. *Oncorhynchus mykiss* (Walbaum), rainbow trout
9. *Poecilia reticulata* Peters, guppy
10. *Lepomis punctatus* (Valenciennes), spotted sunfish

Fishes in the annotated list have an unusually complex synonymy. Accordingly, the list follows the nomenclature of Robins et al. (1991) or Page and Burr (1991); the scientific 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 and Hunt collections and a few in the Forbes and Richardson collections have been re-examined and reidentified.

A summary of collections for all four surveys is given. FR refers to Forbes and Richardson, TH to Thompson and Hunt, LS to Larimore and Smith, and LB to Larimore and Bayley. The numbers following the initials designate the number of localities represented. They are based on the 48 collections of Forbes and Richardson, the 132 collections of Thompson and Hunt, and the 152 collections of Larimore and Smith. All of these collections were recognized by Larimore and Smith (1963). From the recent survey, 141 samples are included. Species taken before or after the regular survey are not tabulated but are mentioned in the discussion. These numbers may be slightly different from those in Tables 3 and 4 analyzing occurrences because those tables excluded "cruising" collections of Larimore and Smith outside the blocked-off sampling areas. Names of drainages from which species were collected are given in parentheses and abbreviated as SF=Salt Fork, MF=Middle Fork, San=Sangamon, Kas=Kaskaskia, and Emb=Embarras. Presence or absence in the Little Vermilion is not as significant in that relatively small drainage as in other drainages in the county where more collections were taken, so is not itemized in this list. The term "all drainages" following a number indicates that all five 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 and Richardson (1908) or Thompson and Hunt (1930). When "?" is followed by "+", the species was identified in extant collections.

Lepisosteidae

***Lepisosteus osseus* (Linnaeus), longnose gar.** One large adult taken by Larimore and Smith in a supplemental collection in the Middle Fork where it leaves the county. The species was probably missed by earlier investigators because of its rarity in the county. In the recent survey (LB), one specimen was collected in the Sangamon, a drainage where it is frequently taken in the lower reaches. LS 1 (MF), LB 1 (San).

Lepisosteus platostomus **Rafinesque, shortnose gar.** The only county record of this large-river gar was in the recent survey (LB) at one station in the Sangamon. LB 1 (San).

Hiodontidae

Hiodon alosoides **(Rafinesque), goldeye.** One specimen known from Champaign County. This specimen, taken from the Kaskaskia River at the lowermost station in the county and reported as *Hiodon tergisus* by Thompson and Hunt, is still extant and is reidentified as *H. alosoides.* It has been reported often from the middle Kaskaskia and Embarras rivers below Champaign County. TH 1 (Kas).

Clupeidae

Dorosoma cepedianum **(Lesueur), gizzard shad.** This species is abundant throughout the state except in extreme northeastern Illinois (Smith 1979). It has extended its range in Champaign County during the past half century probably because of construction of downstream reservoirs. FR 3 (Kas), TH 2 (San), LS 12 (Emb, SF, San), LB 23 (all drainages).

Cyprinidae

Campostoma anomalum **(Rafinesque), central stoneroller.** This fish is assignable to the subspecies *C. a. pullum.* Another stoneroller, *Campostoma oligolepis*, was not distinguished from *C. anomalum* by Forbes and Richardson nor Thompson and Hunt and is not present in extant county collections. Even though it has been taken (two collections) in neighboring counties of the Kaskaskia, we do not believe this rare species has been collected in Champaign County. The central stoneroller has been one of the most common minnows in the county in spite of stream modifications during the century. Forbes and Richardson found that it preferred rocky or sandy creeks with swift to moderate currents. Although early dredging of Champaign County streams removed many rocky riffles, the channelization increased the gradient and left more sand than rocky bottoms, a condition the stoneroller accepted. FR 17 (SF, MF, San), TH 64 (all drainages), LS 102 (all drainages), LB 75 (all drainages).

Carassius auratus **(Linnaeus), goldfish.** This ornamental fish can be found in several Champaign county ponds and has been taken in county streams but with no evidence of reproduction or an established stream population. LS 2 (SF), LB1 (SF).

Cyprinella lutrensis **(Baird & Girard), red shiner.** *Notropis lutrensis* of Larimore and Smith. A species collected in the county since 1928. This aggressive and silt-tolerant species has been moving westward in Illinois and was found to be abundant in the Kaskaskia and upper Sangamon drainages by Larimore and Smith in a variety of river and creek habitats. Page and R. L. Smith (1970) pointed out that the invading red shiner is displacing *Cyprinella spiloptera* and *C. whipplei* through hybridization and aggression in turbid waters of Illinois. Pflieger (1975) showed that the distribution of *C. lutrensis* in Missouri does not overlap those of these other two species. Recent Champaign collections (LB) included *C. lutrensis X C. spiloptera* hybrids but the abundance of the red shiner was greater only in the Middle Fork drainage and less in the Sangamon and Kaskaskia basins than in the preceding survey (see maps and discussion of these species). LS 21 (Kas, San), LB 13 (San, Kas, MF).

Cyprinella spiloptera **(Cope), spotfin shiner.** Included in the composite *Notropis whipplii* of Forbes and Richardson, Thompson and Hunt, and other early authors, and *Notropis spilopterus* of Larimore and Smith. Of the 53 collections of *"N. whipplii"* reported by Thompson and Hunt, 34 are still extant and have been reidentified. Thirty-two of these contained spotfin shiners. Larimore and Smith discussed the proposed subspecies *spilopterus* and *hypsisomatus* in the county. Smith (1979) stated that the spotfin shiner, once virtually statewide, has been decimated by habitat alterations and the invading red shiner. In Champaign County, however, it has occurred in increasing percentages in the collections of the three recent surveys. See *C. whipplei* and *C.*

lutrensis. FR ?, TH 32 of reidentified collections or 50 of all TH collections (Kas, SF, MF, San), LS 63 (all drainages), LB 75 (San, SF, MF, Emb).

***Cyprinella whipplei* Girard, steelcolor shiner.** *Notropis whipplei* of Larimore and Smith. Probably included in the composite *Notropis whipplii* of Forbes and Richardson and found at 16 localities in the 34 reidentified collections of Thompson and Hunt's "*whipplii*." Smith (1979) pointed out that this shiner has retreated in its former range in central Illinois because it has a lower tolerance of deteriorating habitat than do the invading red shiner and the spotfin shiner (see *Cyprinella lutrensis* and *C. spiloptera*). The three recent surveys included about the same percent occurrence. FR ?, TH 16 of reidentified collections or 25 of all TH collections (all drainages), LS 27 (San, Emb, SF, MF), LB 20 (all drainages).

***Cyprinus carpio* Linnaeus, common carp.** Having been first stocked in Illinois in 1879, Forbes and Richardson collected the carp in three of the six Champaign County drainages before the turn of the century. One of the early stockings (1885) included the Sangamon and Kaskaskia drainages of this county. It is occasionally found in fair-sized schools in the larger pools and is frequently caught by anglers. FR 4 (SF, MF, San), TH 11 (not 9 as stated: Emb, SF, San), LS 56 (all drainages), LB 33 (all drainages).

***Ericymba buccata* Cope, silverjaw minnow.** The silverjaw minnow is one of the most abundant fishes in east-central Illinois, with Champaign County being on the western edge of its distribution. Forbes and Richardson did not collect it in the Sangamon, the county's northwestern drainage. Although Thompson and Hunt and Larimore and Smith found it generally abundant across the county, it was drastically reduced in the western drainages (Sangamon and Kaskaskia) during the Larimore and Bayley survey. The silverjaw minnow prefers the clean sandy bottom of headwater streams. Although Trautman (1957) saw Ohio populations decline when silt covered the sands, these two Champaign county drainages with reduced populations have received no more silt than the Salt Fork, where it is still abundant. FR 22 (Kas, SF, Emb, MF), TH 79 drainages), LB 48 (all drainages).

***Hybognathus nuchalis* Agassiz, Mississippi silvery minnow.** The occurrence of this minnow in the county changed between drainages during the century. Forbes and Richardson collected it in four drainages but not in the Kaskaskia. The two surveys that followed, TH and LS, collected it only in the Kaskaskia. Although Smith (1963) collected it in the Kaskaskia in 1961 and L.M. Page in 1970, it was not taken during the recent survey (LB). FR 4 (San, SF, MF), TH 9 (Kas), LS 9 (Kas).

***Hybopsis amblops* (Rafinesque), bigeye chub.** Although not taken in the county in the two recent surveys, it was still present in 1960 in the Middle Fork and Salt Fork in adjacent Vermilion County. In 1992 it was collected in the Little Vermilion, also in Vermilion County, by the Illinois Department of Conservation. Although never widespread in the state, this minnow was previously found in many clear streams with clean bottoms and aquatic vegetation in southeastern Illinois, and Smith (1968) blamed the reduction in these habitats for the disappearance of this chub from the Embarras River in Champaign County. It is presently listed as endangered in Illinois. FR 6 (SF, MF), TH 8 (Emb, SF, MF).

***Hybopsis amnis* (Hubbs & Greene), pallid shiner.** Specimens of this species were referred by Thompson and 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 extant Thompson and Hunt specimens of "*Notropis blennius*" has revealed specimens of *amnis* mixed with *N. stramineus* from three stations on the Sangamon near Fisher. This is reported as *Notropis amnis* by Larimore and Smith. There are no records of this rare shiner in Champaign County since the 1928 collections, but 88 specimens were taken from 1978 to 1986 in a lower reach of the Kankakee River north of Champaign County (Kwak 1991). It is presently listed as endangered in Illinois. TH 3 (San).

***Luxilus chrysocephalus* Rafinesque, striped shiner.** Reported as *Notropis cornutus* by Forbes and Richardson and by Thompson and Hunt, and *Notropis chrysocephalus* by Larimore and Smith. Smith (1979) said this species is generally abundant in the clear, gravelly creeks of east-central Illinois but blamed the shrinkage of its range in the north on siltation, drying of pools in small creeks, and pollution from agriculture. However, its increase and continued wide distribution in Champaign County does not support this reasoning. Larimore and Bayley found it abundant at more stations than in earlier surveys, especially in the Sangamon. FR 9 (SF, San), TH 54 (Kas, SF, MF, San), LS 64 (all drainages), LB 103 (all drainages).

***Lythrurus fumeus* (Evermann), ribbon shiner.** The first confirmed collection of this shiner in the county was by Larimore and Smith in the Embarras in 1959. P.W. Smith and L.M. Page obtained two collections in 1969, also from the Embarras (see Illinois Natural History Survey [INHS] collections). Smith (1979) speculated that the ribbon shiner may be more abundant than before because of its tolerance of turbidity. The five recent collections (LB) confirm this. LS 1 (Emb), LB 5 (Emb).

***Lythrurus umbratilis* (Girard), redfin shiner.** Reported as *Notropis umbratilis atripes* by Forbes and Richardson, Thompson and Hunt, and other early authors, and *N. u. cyanocephalus* by Larimore and Smith. Local populations are extremely variable, and subspecific identification is based on geography. FR 10 (Kas, SF, San), TH 69 (all drainages), LS 97 (all drainages), LB 67 (all drainages).

***Macrohybopsis storeriana* (Kirtland), silver chub.** A specimen from the Middle Fork and one from the Salt Fork were reported by Forbes and Richardson. Another specimen, an individual 4.5 in. long taken on a hook in the Salt Fork River near Homer in July 1952, was reported by M.S. Goldman. The three records for the county are unusual upstream records for this large-river chub. FR 2 (MF, SF).

***Nocomis biguttatus* (Kirtland), hornyhead chub.** Reported as *Hybopsis kentuckiensis* by Forbes and Richardson and by Thompson and Hunt, and *H. biguttata* by Larimore and Smith. Forbes and Richardson pointed out that they had not found this chub south of the Wisconsinan glaciation, although Hankinson (1913) took it commonly in the Embarras around Charleston in Coles County along the southern limit of that glacier. Since the four county surveys (including FR) failed to take it in the Embarras basin, we believe the map dot on the Embarras in the Forbes and Richardson atlas (1908) and duplicated by Smith (1979) should be just over the basin divide in the Salt Fork drainage. Smith (1979) said the hornyhead chub was decimated in central Illinois probably due to siltation and pollution, but the continued abundance in Champaign County does not support that conclusion. The recent survey included a hybrid with *Luxilus chrysocephalus*. FR 10 (SF, MF, San), TH 46 (Kas, MF, San), LS 70 (Kas, SF, MF, San), LB 57 (Kas, SF, San).

***Notemigonus crysoleucas* (Mitchill), golden shiner.** Reported as *Abramis crysoleucas* by Forbes and Richardson, Thompson and Hunt, and other early authors. Considered one of the most tolerant minnows of poor water quality, possibly its decline reflects the reduction in aquatic vegetation caused by the dredging of our marshes and low gradient streams. FR 20 (Kas, SF, MF, San), TH 41 (all drainages), LS 46 (all drainages), LB 12 (all drainages but MF).

***Notropis atherinoides* Rafinesque, emerald shiner.** An abundant minnow in large rivers, it is rare in the small streams of this county. Larimore and Smith collected it at one supplementary station in the Sangamon, none at the regular stations. FR 2 (SF, San), TH 3 (MF), LS 2 (Emb, SF).

***Notropis boops* Gilbert, bigeye shiner.** Reported as *Notropis illecebrosus* by Forbes and Richardson, Thompson and Hunt, and other early authors. Although Forbes and Richardson (1908) collected it in many places in the Vermilion and Little Vermilion rivers in Vermilion County, they collected it at only one station in Champaign County. It has not been collected in Champaign County since 1928 but still occurs in the lower Little Vermilion. This shiner is sporadic in distribution and rare in Illinois (Smith 1979). It is presently listed as endangered in the state. FR 1 (SF), TH 2 (MF).

***Notropis dorsalis* (Agassiz), bigmouth shiner.** Reported as *Notropis gilberti* by Forbes and Richardson, Thompson and Hunt, and other early authors. Champaign County is on the eastern edge of the range of this minnow, which is abundant in the more western prairie streams. Although Smith (1979) plotted one record in Vermilion County, the single records from the Salt Fork (FR) and Middle Fork (LS) given here, as in Larimore and Smith, are unusual for this more western minnow. Channelization of low-gradient streams seems to have created its preferred habitat of unstable sandy bottoms as suggested by its increase in the county from the time of Forbes and Richardson to Larimore and Smith. FR 1 (SF), TH 5 (San), LS 28 (Kas, MF, San), LB 18 (Kas, San).

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

***Notropis rubellus* (Agassiz), rosyface shiner.** Misidentified as *"Notropis atherinoides,* var." by Thompson and Hunt. Collections by Larimore and Smith from the same stations contained *rubellus* and not *atherinoides*. Of the three Thompson and Hunt collections labeled *atherinoides,* the one extant collection contains *rubellus* only. During the recent survey, this large-stream minnow of our northeastern counties was taken in the Middle Fork, Salt Fork (one site in each stream), and at three additional sites in the Salt Fork just downstream and out of the county. TH 3 (MF), LS 6 (MF), LB 2 (MF, SF).

***Notropis stramineus* (Cope), sand shiner.** Included in the composite *Notropis blennius* of Forbes and Richardson, Thompson and Hunt, and other early authors. It has been called *N. deliciosus* and, more recently, *N. ludibundus*. The identity of the Forbes and Richardson specimens is not known, but probably the majority belong to this species. Of the 44 collections of *"blennius"* reported by Thompson and Hunt, 32 are extant and have been reidentified, revealing *stramineus* exclusively, or in part, in all of them. This shiner is generally abundant in the northern four-fifths of the state and throughout Champaign County. FR ?, TH 32 (all drainages), LS 93 (all drainages), LB 75 (all drainages).

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

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

***Phenacobius mirabilis* (Girard), suckermouth minnow.** Although more frequent in the collections of Forbes and Richardson than in those of later surveys, this minnow is still generally distributed throughout the county. FR 18= (Kas, Emb, SF, San), TH 25 (Kas, SF, MF, San), LS 34 (all drainages), LB 23 (San, Kas, MF, SF).

***Pimephales notatus* (Rafinesque), bluntnose minnow.** The most abundant and widespread fish in the county and possibly in most of the eastern states. It tolerates a wide range of stream conditions and is a rapid invader of new or previously disturbed waters. Larimore et al. (1959) found it more than 6 miles upstream—the farthest of 21 reinvading fishes—in a small eastern Champaign County stream that had been dry and without any fishes for 6 months. In spite of its widespread distribution, it has no described subspecies (Smith 1979). FR 37 (all drainages), TH 111 (all drainages), LS 134 (all drainages), LB 111 (all drainages).

***Pimephales promelas* Rafinesque, fathead minnow.** Except for one record in the Kaskaskia, the fathead minnow was limited to the Sangamon River until the recent collections (LB). These recent collections included none from the Sangamon and only four in the Embarras and Salt Fork, where it had not been taken previously in the county. This minnow is the most commonly used bait minnow in the area, which may account for the two new drainage records but not for its apparent disappearance from the Sangamon. FR 4 (San), TH 19 (San), LS 20 (San, Kas), LB 4 (SF, Emb).

***Pimephales vigilax* (Baird & Girard), bullhead minnow.** Reported as *Cliola vigilax* by Forbes and Richardson, Thompson and Hunt, and other early authors. This large-river minnow has disappeared from the county since the time of Thompson and Hunt. FR 6 (San), TH 4 (SF, San).

***Semotilus atromaculatus* (Mitchill), creek chub.** The creek chub is common throughout the county. It is a very invasive species and was among the four species to first reinvade one of our small creeks that had been dry and without fish for 6 months (Larimore et al. 1959). FR 9 (SF, MF, San), TH 101 (all drainages), LS 126 (all drainages), LB 90 (all drainages).

Catostomidae

***Carpiodes carpio* (Rafinesque), river carpsucker.** Larimore and Smith mentioned that this species had been taken in adjacent Vermilion County but did not report the six large specimens they took in Champaign County in the Middle Fork in 1959. In the recent study (LB), the river carpsucker occurred in one collection in the Middle Fork and at four within the Sangamon. Later, Bayley and Dowling (1990) took this carpsucker at two Champaign County stations in the Kaskaskia Basin. LS 1 (MF), LB 5 (MF, San).

***Carpiodes cyprinus* (Lesueur), quillback.** Reported as *Carpiodes velifer* by Forbes and Richardson, Thompson and Hunt, and other early authors, and *C. cyprinus hinei* by Larimore and Smith. Although the quillback occurs statewide and occupies a wide range of stream habitats, it moves in schools and occurs sporadically even in areas where it has been found to be abundant. Although still not common in the Kaskaskia and Embarras, this species is more widespread in the county than before. FR 10 (Kas, SF, MF, San), TH 9 (MF, San), LS 27 (SF, MF, San), LB 33 (SF, MF, Kas, Emb, San).

***Carpiodes velifer* (Rafinesque), highfin carpsucker.** Reported as *Carpiodes difformis* by Forbes and Richardson, Thompson and Hunt, and other early authors. Smith (1979) said it was once the most abundant carpsucker in Illinois, but now is the least. Although less abundant since Forbes and Richardson, it is still widespread in Champaign County. FR 8 (Kas, SF, MF, San), TH 4 (MF, San), LS 9 (SF, MF, San), LB 11 (SF, MF, San).

***Catostomus commersoni* (Lacepède), white sucker.** This sucker is widespread and tolerant of most stream habitats. Although taken in a smaller percentage of the collections in the recent survey (LB) than in previous ones, it was taken in many additional county collections during 1988-1990. FR 14 (SF, MF, San), TH 63 (not 65 as stated: all drainages), LS 76 (all drainages), LB 41 (all drainages).

***Erimyzon oblongus* (Mitchell), creek chubsucker.** Reported as *Erimyzon sucetta oblongus,* a composite of *E. sucetta* and *E.oblongus,* by Forbes and Richardson, Thompson and Hunt, and other early authors. There is no evidence that *E. sucetta* ever occurred within the county, although it has been stocked as forage in several ponds and is known from deep quarries in adjacent Vermilion County. FR 22 (all drainages), TH 43 (all drainages), LS 79 (all drainages), LB 59 (all drainages).

***Hypentelium nigricans* (Lesueur), northern hogsucker.** Reported as *Catostomus nigricans* by Forbes and Richardson, Thompson and Hunt, and other early authors. Smith (1979) said this sucker is "intolerant of pollution, silt, and the modification of stream channels," causing its decimation in many streams of Illinois. Such a fate does not seem true in Champaign County, where it occurs in all basins. It has been taken in more basins and in a greater percentage of samples in the surveys since Forbes and Richardson. FR 7 (SF, MF, San), TH 27 (all drainages), LS 42 (all drainages), LB 29 (all drainages).

***Ictiobus bubalus* (Rafinesque), smallmouth buffalo.** A single specimen of this big-river sucker was taken in the county on the lower Sangamon River by Forbes and Richardson. It was taken in the upper Sangamon during a revisit to a regular station (LB) and at a nearby station by Bayley and Dowling (1990) soon afterwards. FR 1 (San).

***Ictiobus cyprinellus* (Valenciennes), bigmouth buffalo.** One specimen reported from the lower Sangamon by Thompson and Hunt. In the recent survey (LB) this sucker was taken in the upper Sangamon. Two years later, it was collected by Bayley and Dowling (1990) at one station in the upper Kaskaskia of Champaign County. TH 1 (San), LB 1 (San).

***Ictiobus niger* (Rafinesque), black buffalo.** Reported as *Ictiobus urus* by Thompson and Hunt. They collected a single specimen in the county on the Sangamon River. In 1950, M.S. Goldman of Urbana caught one near Mahomet in the Sangamon River. TH 1 (San).

***Minytrema melanops* (Rafinesque), spotted sucker.** The frequency of occurrence of this species has dramatically declined in this county from the time of Forbes and Richardson to the collections of Larimore and Smith, when it was found in only one collection in the Little Vermilion basin. In the recent survey (LB), it had increased to nine collections in three basins. This sucker is usually associated with submerged vegetation, and reductions in abundance followed reductions in aquatic vegetation. FR 15 (Kas, SF, MF, San), TH 4 (not 5 as stated; Kas, SF), LB 9 (Emb, MF, SF).

***Moxostoma anisurum* (Rafinesque), silver redhorse.** This species seems to have increased in Champaign County since the first two surveys, especially in the Middle Fork, where it had not been recorded and where several large collections were taken in the present study. TH 1 (San), LS 7 (SF, San), LB 11 (MF, SF, San).

***Moxostoma duquesnei* (Lesueur), black redhorse.** Not distinguished from *M. erythrurum* by Forbes and Richardson nor Thompson and Hunt. One of the extant Forbes and Richardson collections of *M. erythrurum* includes this species taken in the county from the Salt Fork near Homer by T. Large in 1899. It was not taken by Larimore and Smith in the county but was found downstream in the Salt Fork. The black redhorse occurs only sporadically in Illinois. In spite of the early confusion with its identification, it seems certain that this redhorse has increased in this county, having been taken in four drainages in the recent (LB) survey and in several additional collections soon afterwards. LB 7 (MF, San, SF, Emb).

***Moxostoma erythrurum* (Rafinesque), golden redhorse.** Reported as *Moxostoma aureolum* by Forbes and Richardson, Thompson and Hunt, and other early authors, who presumably based their identifications on specimens of this species. The superficially similar *M. duquesnei* (see preceding note) was not distinguished from *M. erythrurum* during the first two surveys. The most abundant and widespread redhorse in Champaign County and the state, it has been common in the county throughout the surveys. FR 11 (SF, MF, San), TH 22 (all drainages), LS 28 (Emb, SF, MF, San), LB 33 (all drainages).

***Moxostoma macrolepidotum* (Lesueur), shorthead redhorse.** Reported as *Moxostoma breviceps* by Forbes and Richardson, Thompson and Hunt, and other early authors, then later called *M. aureolum* almost to the time of Larimore and Smith, who used the current name. This redhorse was taken in the Middle Fork in several collections (Peterson and Bayley 1993) soon after the recent (LB) survey. It had not been recorded in that basin since one collection by Forbes and Richardson. FR 5 (SF, MF), TH 6 (Kas, San), LS 8 (San), LB 10 (San).

Ictaluridae

***Ameiurus melas* (Rafinesque), black bullhead.** Reported as *Ictalurus melas* by Larimore and Smith. Although still very widespread, the black bullhead is not as common in the county nor in the state as during the time of Forbes and Richardson. Smith (1979) noted, "In view of its wide ecological tolerance, the apparent decimation cannot be easily explained." In contrast, the yellow bullhead has increased during this time. FR 12 (Kas, SF, MF, San), TH 12 (not 13 as stated: all drainages), LS 7 (all drainages), LB 17 (all drainages).

Ameiurus natalis **(Lesueur), yellow bullhead.** Reported as *Ictalurus natalis* by Larimore and Smith. Forbes and Richardson (1908) noted that the yellow bullhead was much less common in Illinois than the black bullhead. In Champaign County, the yellow bullhead has increased significantly during this century, while the black bullhead has shown no significant change. (Table 4 see black bullhead). FR 6 (Kas, SF, Emb), TH 15 (all drainages), LS 38 (all drainages), LB 69 (all drainages).

Ictalurus punctatus **(Rafinesque), channel catfish.** Although widely stocked in fishing ponds of the county, the channel catfish has changed little in its frequency of occurrence through the century. The regular surveys have not recorded it from the Kaskaskia in the county, even though it is common farther downstream and has been stocked in the upper reaches. Peterson and Bayley (1993) collected it (but not mentioned in published account) at one station in the Kaskaskia in 1990. FR 4 (SF, MF, San), TH 11 (not 8 as stated: SF, San), LS 17 (SF, San, MF), LB 12 (SF, San, MF, Emb).

Noturus exilis **Nelson, slender madtom.** Reported as *Schilbeodes exilis* by Thompson and Hunt, who recorded the only collections from the county. TH 2 (MF, San).

Noturus flavus **Rafinesque, stonecat.** The increased occurrence of the stonecat during the past century does not reflect any harmful effects of siltation on the rocky riffles which it prefers. FR 1 (San), TH 5 (SF, MF, San), LS 22 (SF, MF, San), LB 12 (SF, MF, San).

Noturus gyrinus **(Mitchill), tadpole madtom.** Reported as *Schilbeodes gyrinus* by Forbes and Richardson, Thompson and Hunt, and other early authors. This madtom was taken relatively often during the first survey (FR) and during the recent survey (LB). Because of its tolerance of mucky bottoms, sedimentation is not likely to be the cause of its low occurrence in the two middle surveys (TH and LS). FR 13 (Kas, SF, San), TH 8 (not 7 as stated: SF), LS 18 (Kas, SF, San), LB 30 (Kas, SF, San).

Noturus miurus **Jordan, brindled madtom.** Reported as *Schilbeodes miurus* by Forbes and Richardson, Thompson and Hunt, and other early authors. FR 6 (SF), TH 2 (not 1 as stated: SF), LS 8 (Emb, SF, MF), LB 5 (Emb, MF).

Noturus nocturnus **Jordan & Gilbert, freckled madtom.** The first specimens recorded in the county were seined by Larimore and Smith from a pool over mixed sand-gravel and the other from a fast riffle in the middle Sangamon River. The Sangamon population may have expanded; five collections were taken in the recent (LB) survey. LS 2 (San), LB 5 (San).

Pylodictis olivaris **(Rafinesque), flathead catfish.** Reported as *Leptops olivaris* by Thompson and Hunt. The flathead is probably more common than the available records indicate. Large individuals are frequently taken by fishermen from the Sangamon, Middle Fork, and Salt Fork. TH 1 (San), LS 4 (MF, SF, San), LB 4 (San, SF).

Esocidae

Esox americanus **Gmelin, grass pickerel.** Reported as *Esox vermiculatus* by Forbes and Richardson, Thompson and Hunt, and by other early authors, and as *E. americanus vermiculatus* by Larimore and Smith, a subspecies still recognized. This widespread species was probably abundant in the marshes and weedy streams of the county when Forbes and Richardson started collecting. They did not collect it in the Embarras drainage of the county, even though they reported it (1908) as abundant in other parts of that basin. Smith (1979) speculated that the loss of aquatic vegetation and siltation has reduced their numbers. But the recent survey (LB) showed it had increased as water quality in several headwater reaches improved. FR 10 (Kas, SF, MF, San), TH 26 (all but MF), LS 17 (all drainages), LB 57 (all drainages).

Esox lucius **Linnaeus, northern pike.** Early angling information suggests that this pike was often taken around the marshes of east-central Illinois. Since the early 1970s, it has been stocked in Homer Lake and other county lakes. Specimens from the Embarras and Salt

Fork taken in the early 1970s are in the INHS collection. LB 1 (SF).

Aphredoderidae

***Aphredoderus sayanus* (Gilliams), pirate perch.** It is surprising that Forbes and Richardson did not collect more from the less disturbed marshes and mucky drainages of their time. They did not report it from the Kaskaskia River in the county even though Luce (1933) found it in abundance there and it was collected in the Kaskaskia in all three more recent surveys. FR 1 (San), TH 12 (Kas, Emb, San), LS 13 (Kas, Emb, San), LB 12 (San, Kas, Emb).

Fundulidae

***Fundulus notatus* (Rafinesque), blackstripe topminnow.** This fish has been common, often abundant, in all surveys and increased strikingly in the more recent (LB) survey, when it was often taken in large numbers. FR 14 (Kas, Emb, SF, San), TH 41 (not 43 as stated: all drainages), LS 54 (all drainages), LB 98 (all drainages).

Poeciliidae

***Gambusia affinis* (Baird & Girard), western mosquitofish.** Apparently a temporary resident in the Salt Fork and a small stream northwest of Homer. LS 2 (SF).

Atherinidae

***Labidesthes sicculus* (Cope), brook silverside.** This large-river, backwater fish was never common in the county and is now rarer than earlier. FR 6 (SF, San), TH 5 (not 3 as stated: SF), LS 3 (SF), LB 2 (SF).

Moronidae

***Morone chrysops* (Rafinesque), white bass.** After development of fish populations in newly constructed Lake Shelbyville in the 1970s, white bass often move into the headwaters of the Kaskaskia during high waters of the spring months, often in large numbers. The recent (LB) collection in the Sangamon no doubt came from Lake Decatur, where they have been stocked. LB 7 (San).

***Morone mississippiensis* Jordan & Eigenmann, yellow bass.** *Roccus mississippiensis* of Larimore and Smith. The first records for Champaign County were by M.S. Goldman, a local fisherman, who caught numerous yellow bass from the Sangamon in 1955; then Larimore and Smith took specimens there in November 1957. The Sangamon River fish presumably migrated upstream from the Lake Decatur population. LS 3 (Kas, San).

Centrarchidae

***Ambloplites rupestris* (Rafinesque), rock bass.** Forbes and Richardson collected the rock bass in east-central Illinois only in the southern portion in the middle Kaskaskia River. Thompson and Hunt took the first one in the county from the Salt Fork. In the two recent surveys (LS, LB), it was taken in 16 and 15 collections, respectively, from the Sangamon, Salt Fork, and Middle Fork. The rock bass is known to prefer clear, silt-free, rocky streams, so it is especially interesting that it has increased in this area during the second half of the century when siltation was thought to be increasing and limiting many fishes. TH 1 (SF), LS 16 (SF, MF, San), LB 15 (SF, MF, San).

***Lepomis cyanellus* Rafinesque, green sunfish.** Frequently hybridizes with bluegill and longear sunfish. Because of its presence in almost all stream habitats, one cannot draw any conclusions from its former or present distribution in Champaign County. FR 23 (all drainages), TH 38 (all drainages), LS 75 (all drainages), LB 83 (all drainages).

***Lepomis gulosus* (Cuvier), warmouth.** *Chaenobryttus gulosus* of Forbes and Richardson, Thompson and Hunt, and Larimore and Smith. The warmouth prefers soft-bottom ponds and sloughs rather than streams. Fish taken in the first (FR) survey may have come from marshes remaining after extensive ditching of the streams or from Crystal Lake in Urbana, where the state held fish for stocking. FR 3 (Kas), TH 1 (SF), LS 1 (San).

***Lepomis humilis* (Girard), orangespotted sunfish.** Although preferring silty, soft-bottom pools, this sunfish is less abundant in the county today than during the Forbes and Richardson survey. Smith (1979) speculated that it may have been abundant in the sloughs and meandering streams before the wet prairie was drained. FR 16 (Kas, SF, MF, San), TH 13 (SF, MF, San), LS 9 (SF, MF, San), LB 8 (SF, MF, San, Kas).

Lepomis macrochirus **Rafinesque, bluegill.** Reported as *Lepomis pallidus* by Forbes and Richardson, Thompson and Hunt, and other early authors. The bluegill has increased rapidly in Champaign County during the past half century, possibly because of widespread stocking of ponds and escapes to county streams. FR 2 (SF, San), TH 1 (SF), LS 16 (Kas, SF, San), LB 44 (all drainages).

Lepomis megalotis **(Rafinesque), longear sunfish.** Smith (1979) said the longear is less tolerant of silt and pollution than other Illinois sunfishes. The striking increase in collections of this sunfish species during the recent survey (LB) may reflect an improvement in water quality in our streams. FR 16 (Kas, SF, MF), TH 37 (not 39 as stated: all drainages), LS 44 (all drainages), LB 101 (all drainages).

Lepomis microlophus **(Günther), redear sunfish.** Formerly known as *Eupomotis heros.* The redear sunfish has been widely stocked in ponds of the county since the early 1950s, after which fishermen began catching this species in county streams, especially the Sangamon; Larimore and Smith collected it in the Kaskaskia. The recent survey (LB) included two collections from the Salt Fork. It is questionable whether it has been established in the streams of the county. LS 1 (Kas), LB 2 (SF).

Micropterus dolomieu **Lacepède, smallmouth bass.** The past three surveys have shown good populations in the Sangamon and Middle Fork with only occasional occurrences in the Salt Fork. However, collections during the two years (1989-1990) following the recent survey included smallmouth bass at many locations much farther upstream in the Salt Fork, into the dredged upstream reaches of drifting sand bedload, and small rubble, not considered good smallmouth habitat. Fishermen were catching smallmouth bass up to 14 in. long even near the Urbana-Champaign waste treatment plant. The wide range in all sizes taken suggests they were not from a single, unusually successful year class. The physical habitat may have changed very little, but the water quality improved dramatically following cleanup of municipal wastes in the 1970s and 1980s. FR 1 (SF), TH 16 (SF, MF, San), LS 37 (Kas, SF, MF, San), LB 28 (SF, MF, San).

Micropterus punctulatus **(Rafinesque), spotted bass.** Probably included in the composite *Micropterus salmoides* of Forbes and Richardson, Thompson and Hunt, and other early authors. Their specimens of "*salmoides*" are not available for re-examination. In the year (1989) following the recent survey (LB), the first drainage records of spotted bass were taken from the Kaskaskia and Sangamon rivers. Occurrences in the upper Salt Fork follow a pattern similar to that of the smallmouth bass (see preceding comments). FR ?, TH ?, LS 9 (SF, MF), LB 15 (MF, SF, Emb).

Micropterus salmoides **(Lacepède), largemouth bass.** Included in the composite *Micropterus salmoides* of Forbes and Richardson, Thompson and Hunt, and other early authors. The increased occurrence in the county probably is a result of the widespread stocking of this bass in ponds and lakes, and movement from downstream reservoirs, such as Lake Decatur and Lake Shelbyville. FR ?, TH ?, LS 14 (SF, MF, San), LB 24 (all drainages).

Pomoxis annularis **Rafinesque, white crappie.** Stocking of ponds and lakes during the time of Larimore and Smith may account for the increased distribution observed in that survey. FR 4 (Emb, SF, San), TH 2 (San), LS 16 (Kas, SF, MF, San), LB 8 (Kas, San).

Pomoxis nigromaculatus **(Lesueur), black crappie.** Reported as *Pomoxis sparoides* by Forbes and Richardson, Thompson and Hunt, and other early authors. Although 15% of Forbes and Richardson's collections, from three basins, included this species, it has never been abundant in the county. FR 7 (Kas, SF, San), TH 3 (San), LS 2 (SF, San), LB 2 (San).

Percidae

Ammocrypta pellucida **(Putnam), eastern sand darter.** Although occurring in the middle Embarras River, this darter appears to be limited to the Middle Fork in Champaign County. Smith (1979) said it was common in the Middle Fork but the recent (LB) survey failed to collect it. Presently listed as endangered in Illinois. TH 2 (MF), LS 3 (MF).

Etheostoma asprigene **(Forbes), mud darter.** Reported as *Etheostoma jessiae* by Forbes and Richardson. Although fairly common in the middle Kaskaskia River, this darter is rare in the small streams of Champaign County. FR 2 (not 1 as stated by Thompson and Hunt: SF, San), LS 1 (San), LB 1 (Emb).

Etheostoma blennioides **Rafinesque, greenside darter.** Reported as *Diplesion blennioides* by Forbes and Richardson, Thompson and Hunt, and other early authors. The frequency of occurrence of this darter declined after the time of Forbes and Richardson, even though Forbes and Richardson collected it only in the Salt Fork while later surveys took it in the Middle Fork and Embarras rivers. These three drainages are on the western edge of the Illinois range of this species. Although never found in abundance, its preference for clean rocky riffles has not suppressed its distribution in Champaign County. FR 7 (SF), TH 10 (Emb, SF, MF), LS 13 (Emb, LV, SF, MF), LB 3 (KAS, MF).

Etheostoma caeruleum **Storer, rainbow darter.** Probably included in the composite *Etheostoma* "*coeruleum*" of Forbes and Richardson. Seven localities represented among the 11 extant collections of Thompson and Hunt. No doubt that early dredging eliminated some of the tree-lined rocky runs preferred by this darter; however, there is no evidence that its distribution in the county has changed during the past half century. FR ?, TH 7+ (Emb, SF, MF), LS 7 (Kas, Emb, SF, MF), LB 9 (MF, SF, Emb).

Etheostoma chlorosomum **(Hay), bluntnose darter.** Reported as *Boleosoma camurum* by Forbes and Richardson, Thompson and Hunt, and other early authors. Page (1983) pointed out that this darter of pools and oxbows along lowland streams increases in occurrence southward in its range. It has been reported in the lower Embarras (Durham 1993) and the middle Kaskaskia (Larimore and Fritz 1993). FR 1 (San), TH 1 (Kas).

Etheostoma flabellare **Rafinesque, fantail darter.** Twelve percent of the collections in the second (TH) and third (LS) surveys included the fantail darter. Why the recent (LB) survey took this darter in only one collection (in the Sangamon) is not understood. FR 2 (SF), TH 16 (not 14 as stated: Emb, SF, MF, San), LS 18 (SF, MF, San), LB 1 (San).

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

Etheostoma nigrum **Rafinesque, johnny darter.** Reported as *Boleosoma nigrum* by Forbes and Richardson, Thompson and Hunt, and other early authors. Larimore and Smith assigned the Champaign County material to the nominate subspecies by geographic basis. This darter of sand-bottom pools of creeks is widespread and often abundant in Champaign County and most of Illinois. FR 19 (Emb, SF, San), TH 82 (all drainages), LS 80 (all drainages), LB 42 (all drainages).

Etheostoma spectabile **(Agassiz), orangethroat darter.** Probably included in the composite *Etheostoma* "*coeruleum*" of Forbes and Richardson and found in 4 of the 11 extant Thompson and Hunt collections. The occurrence of this darter (before it was taxonomically recognized) in the county during the first half of the century is uncertain. Because it prefers riffles and shallow pools of creeks with small-gravel bottoms, a common habitat in the county, the orangethroat darter may have become more common after the marshes were dredged. Larimore et al. (1952) found its abundance increased quickly upstream in the open, unwooded reaches of Jordan Creek in Vermilion County, replacing the rainbow darter, which was more abundant in the downstream wooded area. FR ?, TH 4+ (San), LS 60 (all drainages), LB 34 (Kas, San, SF). Although the orangethroat darter was not taken in the Embarras and Middle Fork drainages during the recent survey, it was collected there in the following year.

***Etheostoma zonale* (Cope), banded darter.** Since this darter is most often found in the northern part of the state, the collections from the Sangamon during the second (TH) and third (LS) surveys are unusual southern records. TH 8 (San), LS 6 (San).

***Percina caprodes* (Rafinesque), logperch.** This large darter occurs throughout the county but has been taken in relatively few collections in each survey. FR 2 (SF, San), TH 2 (Kas, MF), LS 10 (all drainages except SF), LB 4 (MF, Kas, San).

***Percina maculata* (Girard), blackside darter.** Reported as *Hadropterus aspro* by Forbes and Richardson, Thompson and Hunt, and other early authors. Smith (1979) speculated that it was once abundant in the clear, prairie streams of Illinois. Although it occurred more frequently in the collections of Forbes and Richardson than in the recent (LB) survey, it was just as often taken in the third (LS) survey as the first (FR) and has, through the surveys, appeared in more drainage basins (two drainages in first survey, four in following surveys). FR 15 (SF, San), TH 24 (all drainages), LS 49 (all drainages), LB 13 (all drainages).

***Percina phoxocephala* (Nelson), slenderhead darter.** Reported as *Hadropterus phoxocephalus* by Forbes and Richardson, Thompson and Hunt, and other early authors. FR 3 (SF, San), TH 8 (SF, MF, San), LS 18 (SF, MF, San), LB 3 (Kas, Emb, MF).

***Percina sciera* (Swain), dusky darter.** Forbes and Richardson recorded two specimens collected at a Sangamon station but this record may be in error, as suggested by the original note. These Sangamon records are interesting since the species had not been recorded outside the Wabash Basin in Illinois. Buth (1974) reported collecting one specimen from the Embarras River in 1971. LS 1 (MF), LB 3 (MF, Emb).

***Stizostedion vitreum* (Mitchill), walleye.** This popular sportfish was stocked during the late 1980s in lakes of the Salt Fork and Sangamon drainages. Soon afterwards it was being caught by fishermen in these rivers within Champaign County. LB 1 (San).

Sciaenidae

***Aplodinotus grunniens* Rafinesque, freshwater drum.** The drum is a sporadic visitor from downstream in the Sangamon and Kaskaskia rivers. TH 3 (San), LS 4 (San), LB 13 (San, Kas).

APPENDIX 2

SPECIES DISTRIBUTION MAPS FOR ALL FOUR SURVEYS

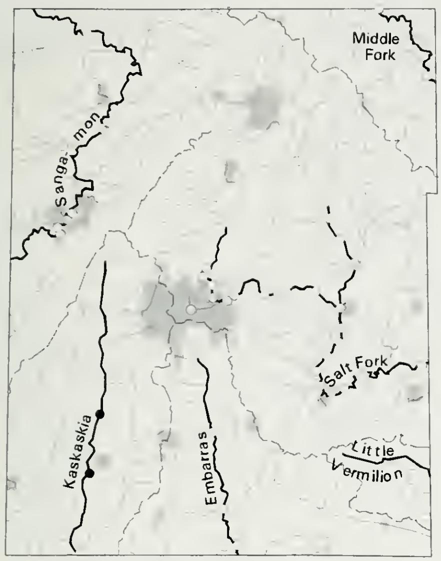
Forbes and Richardson (1889-91)

Thompson and Hunt (1928-29)

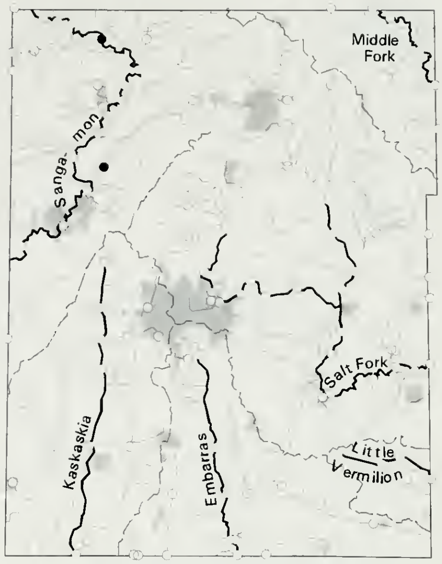
Larimore and Smith (1959-60)

Larimore and Bayley (1987-88)

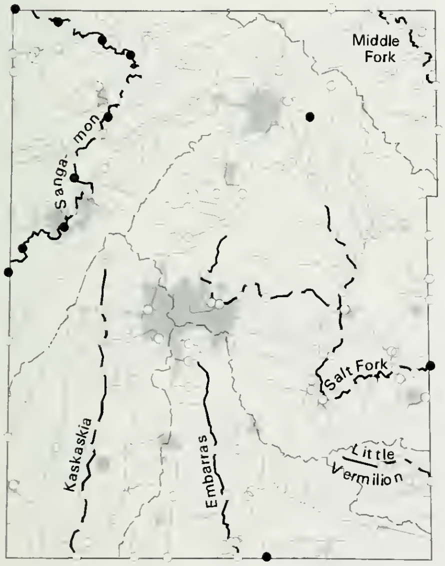
Figure 1



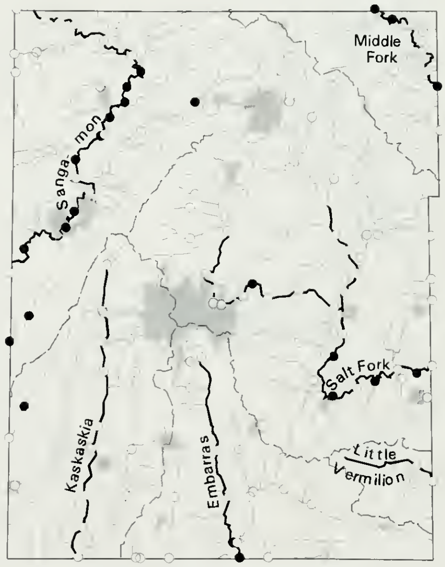
Forbes & Richardson (1889-91)



Thompson & Hunt (1928-29)



Larimore & Smith (1959-60)



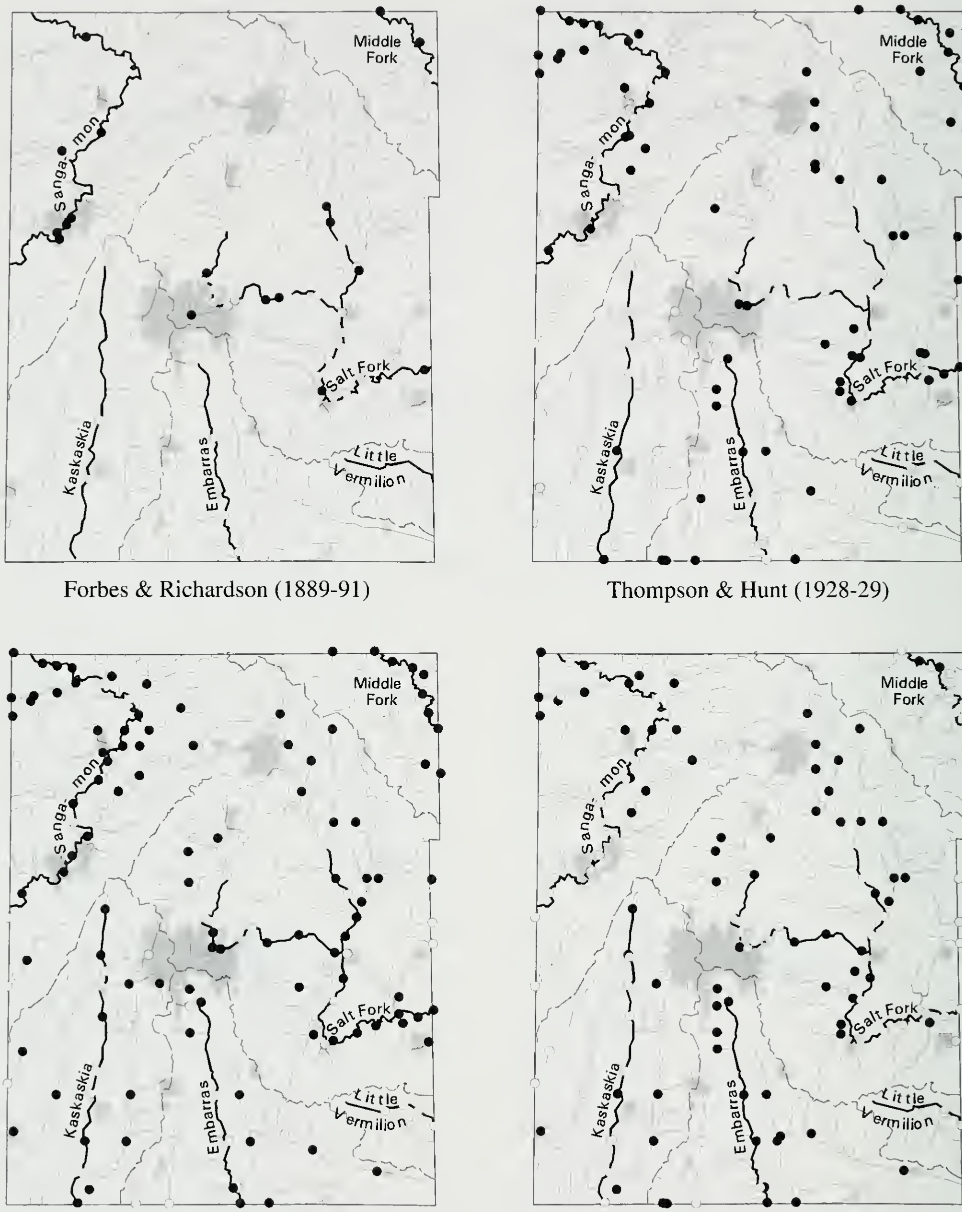
Larimore & Bayley (1987-88)

***Dorosoma cepedianum*, gizzard shad**

○ = species absent

● = species present

Figure 2



Forbes & Richardson (1889-91)

Thompson & Hunt (1928-29)

Larimore & Smith (1959-60)

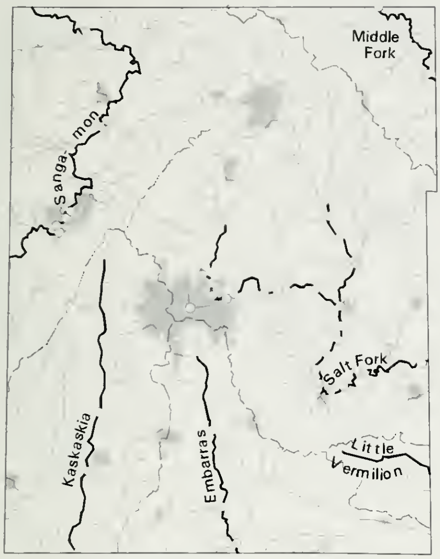
Larimore & Bayley (1987-88)

Campostoma anomalum, central stoneroller

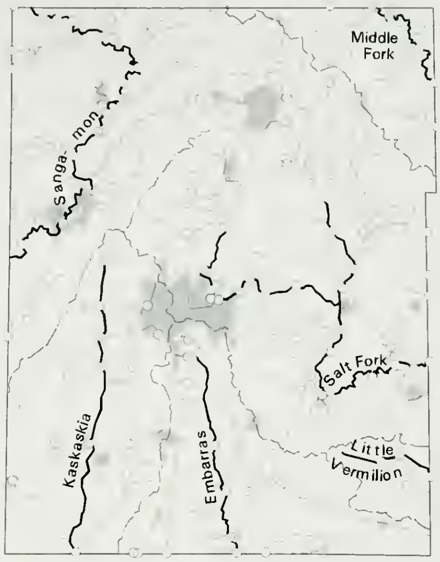
○ = species absent

● = species present

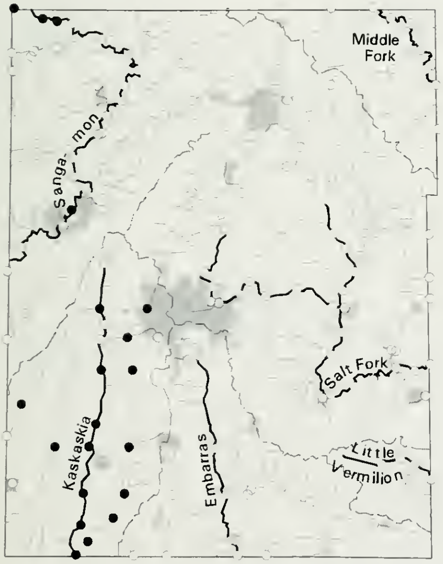
Figure 3



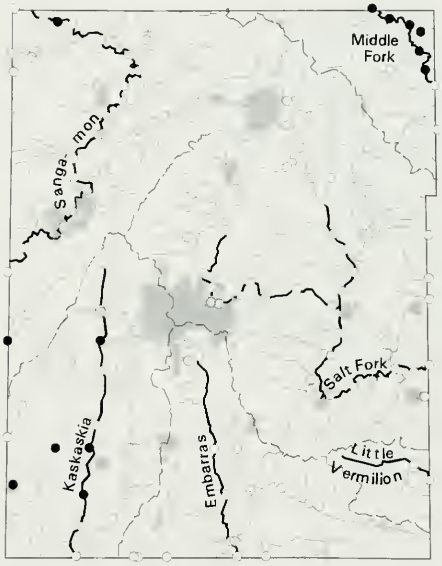
Forbes & Richardson (1889-91)



Thompson & Hunt (1928-29)



Larimore & Smith (1959-60)



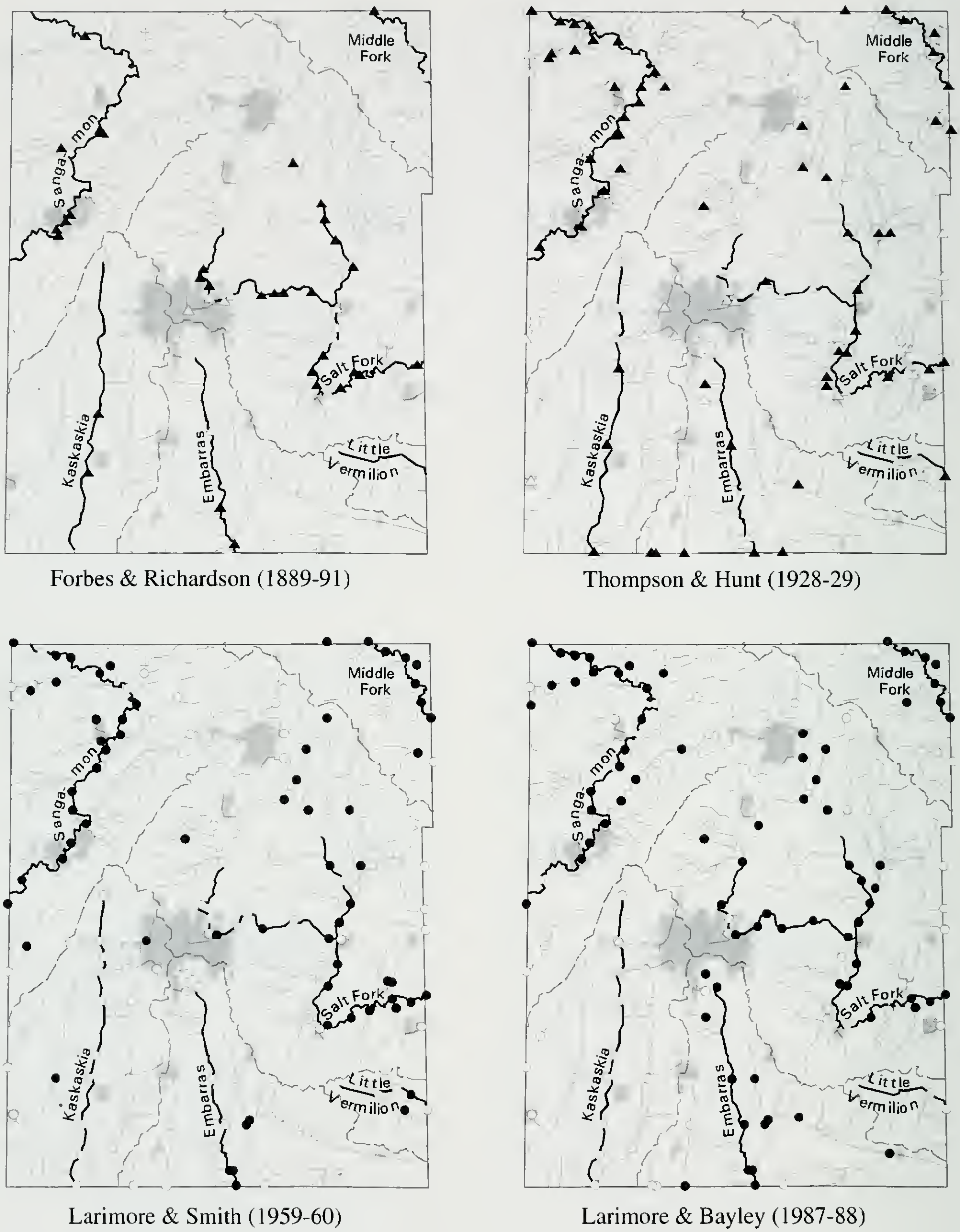
Larimore & Bayley (1987-88)

Cyprinella lutrensis, red shiner

○ = species absent

● = species present

Figure 4



***Cyprinella spiloptera*, spotfin shiner**

Composite with *C. whipplei*, steelcolor shiner

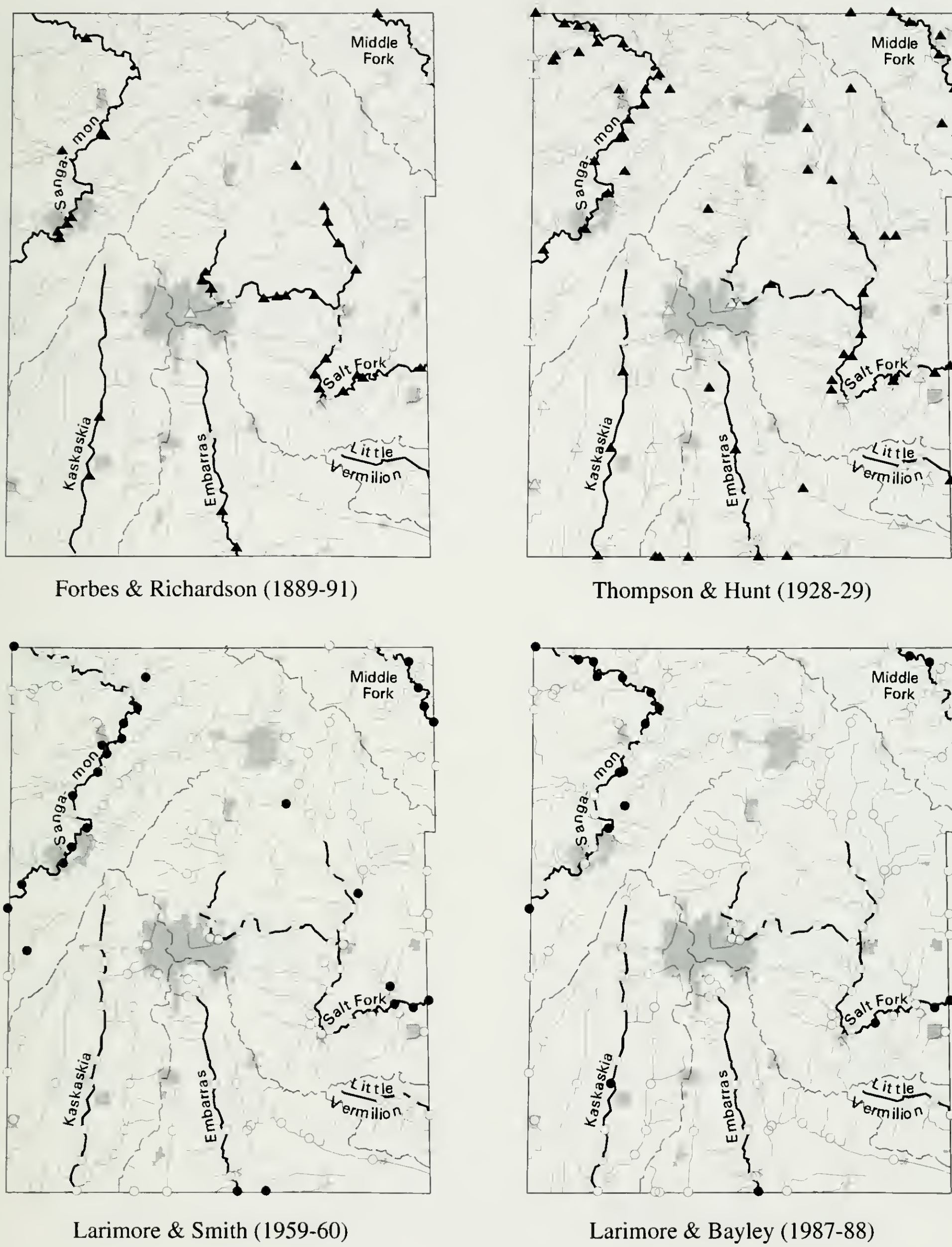
○ = species absent

● = species present

△ = composite absent

▲ = composite present

Figure 5



***Cyprinella whipplei*, steelcolor shiner**

Composite with *C. spiloptera*, spotfin shiner

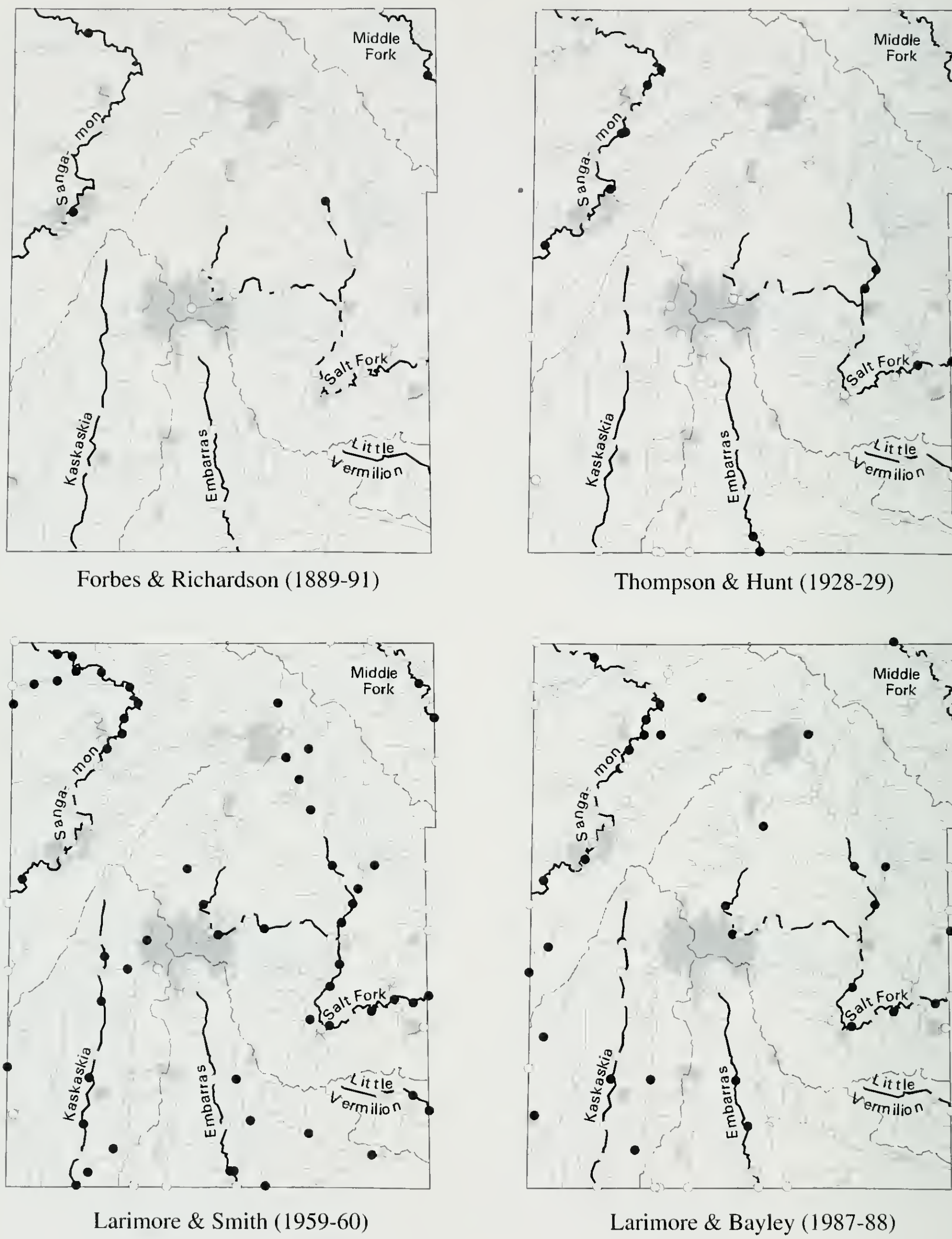
○ = species absent

● = species present

△ = composite absent

▲ = composite present

Figure 6

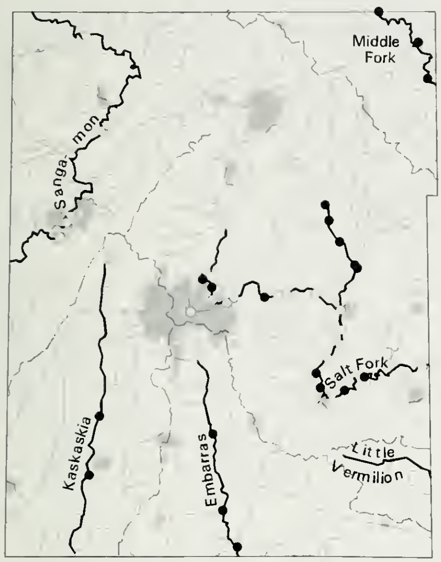


***Cyprinus carpio*, common carp**

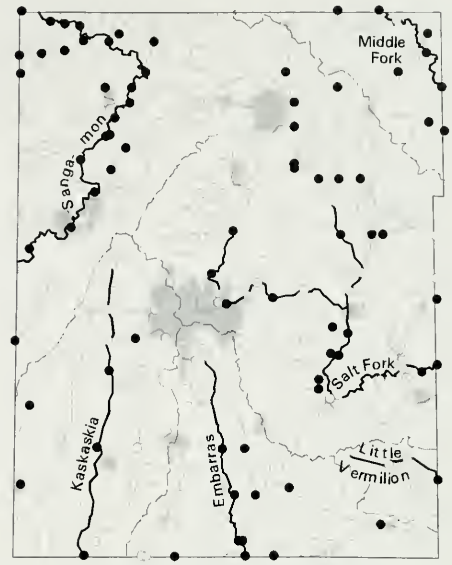
○ = species absent

● = species present

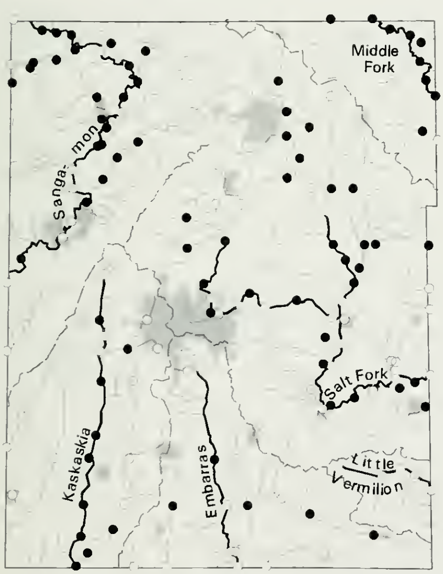
Figure 7



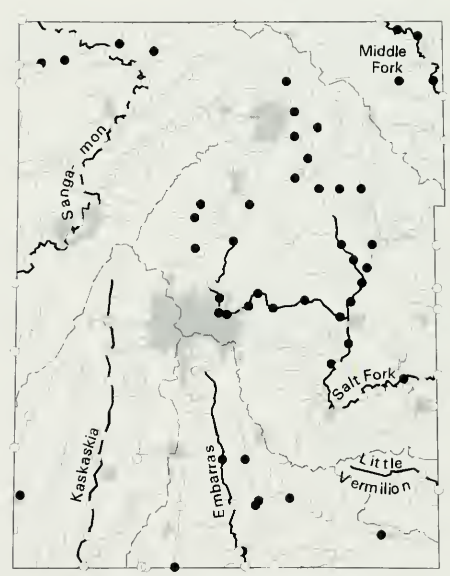
Forbes & Richardson (1889-91)



Thompson & Hunt (1928-29)



Larimore & Smith (1959-60)



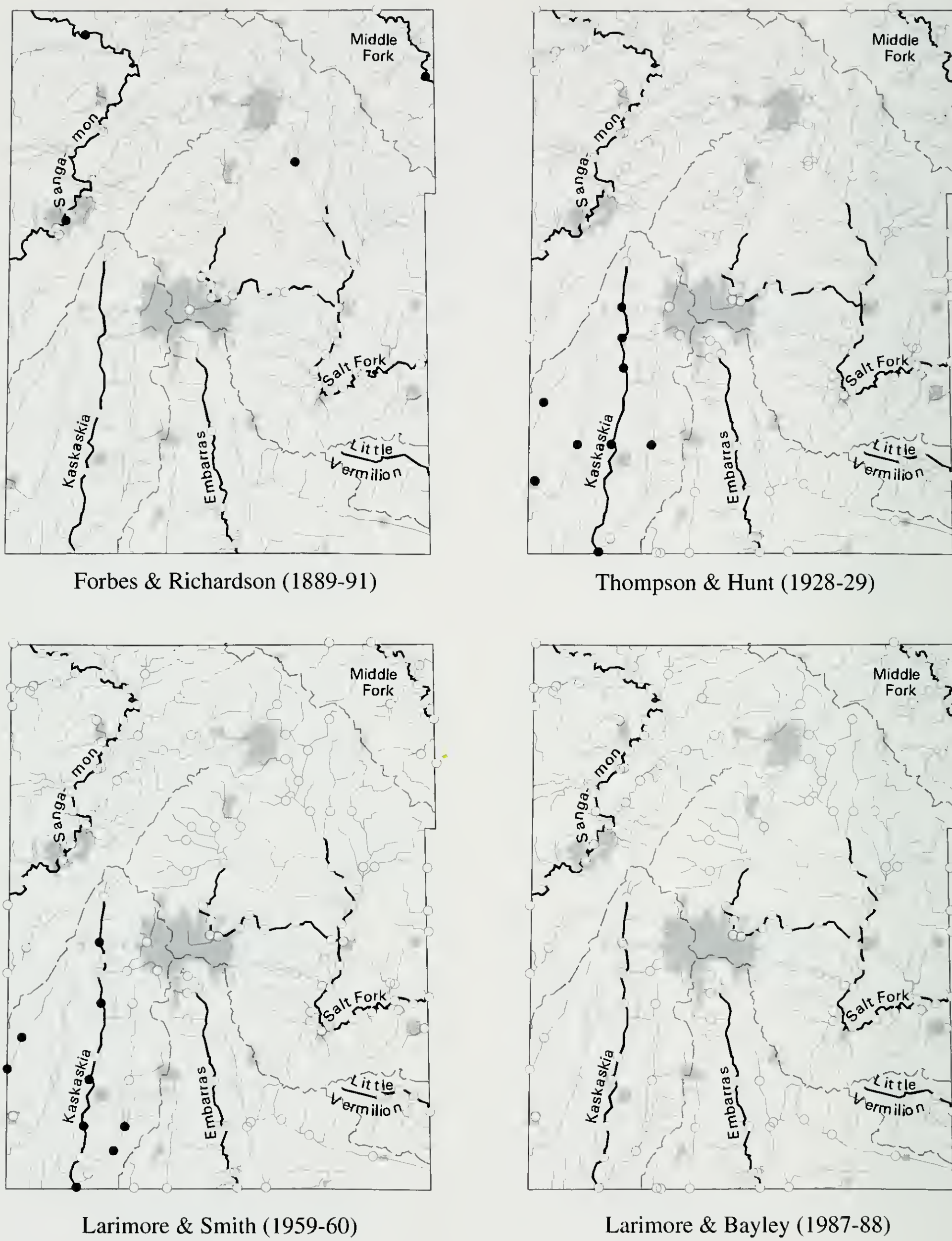
Larimore & Bayley (1987-88)

***Ericymba buccata*, silverjaw minnow**

○ = species absent

● = species present

Figure 8

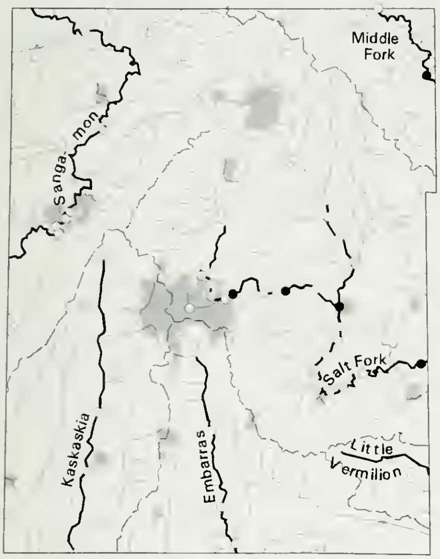


***Hybognathus nuchalis*, Mississippi silvery minnow**

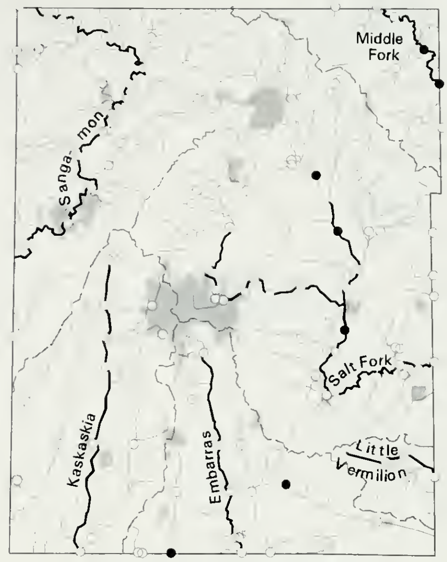
○ = species absent

● = species present

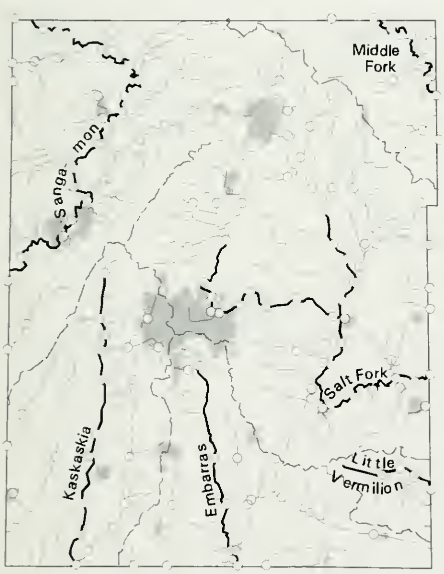
Figure 9



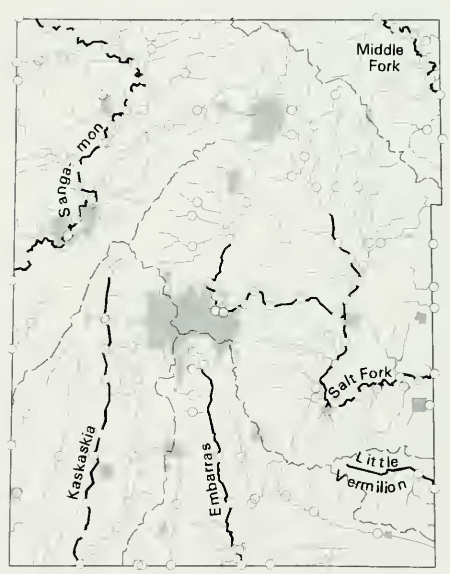
Forbes & Richardson (1889-91)



Thompson & Hunt (1928-29)



Larimore & Smith (1959-60)



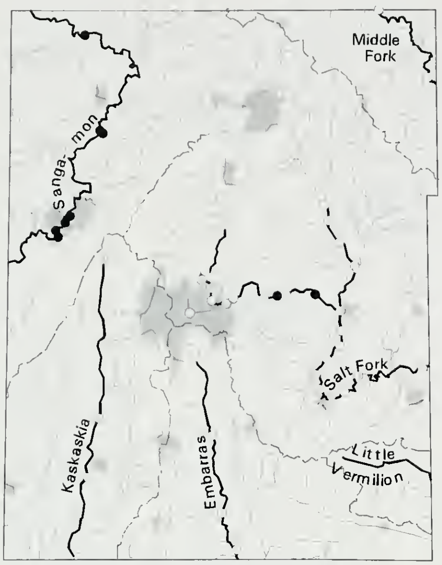
Larimore & Bayley (1987-88)

***Hybopsis amblops*, bigeye chub**

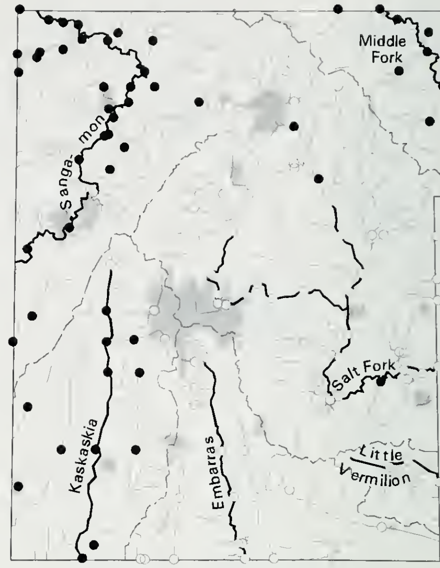
○ = species absent

● = species present

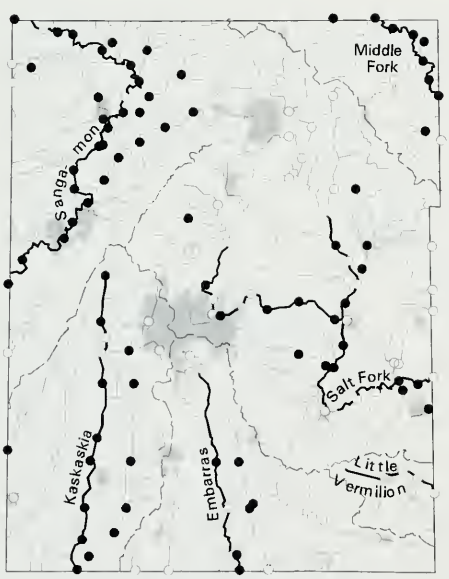
Figure 10



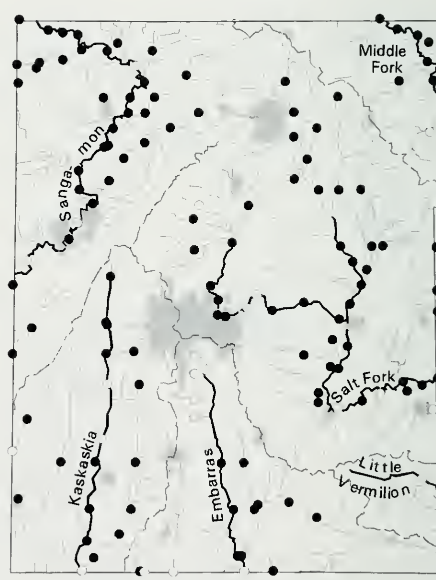
Forbes & Richardson (1889-91)



Thompson & Hunt (1928-29)



Larimore & Smith (1959-60)



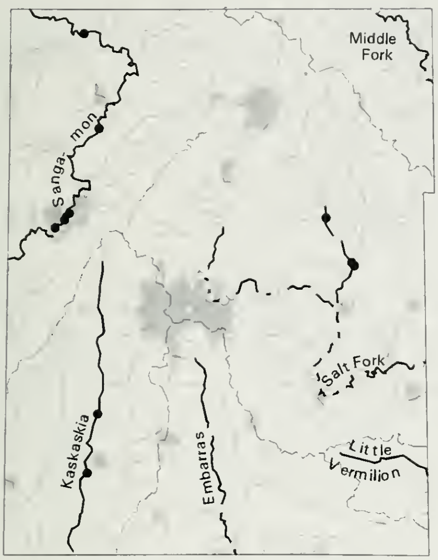
Larimore & Bayley (1987-88)

***Luxilus chrysocephalus*, striped shiner**

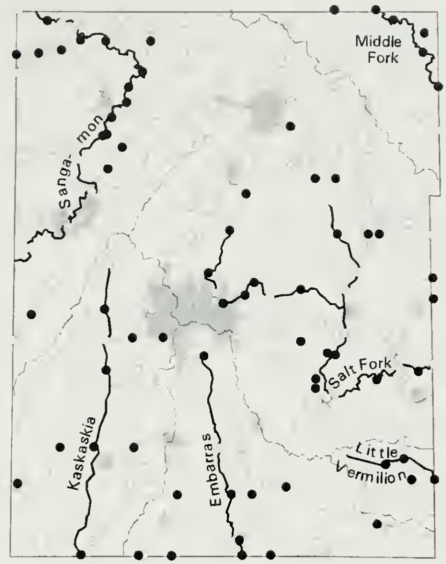
○ = species absent

● = species present

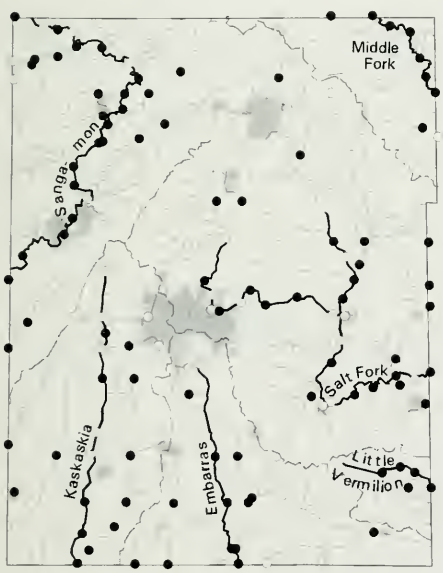
Figure 11



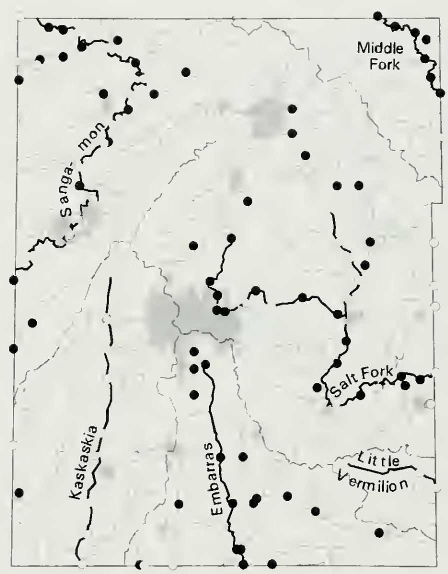
Forbes & Richardson (1889-91)



Thompson & Hunt (1928-29)



Larimore & Smith (1959-60)



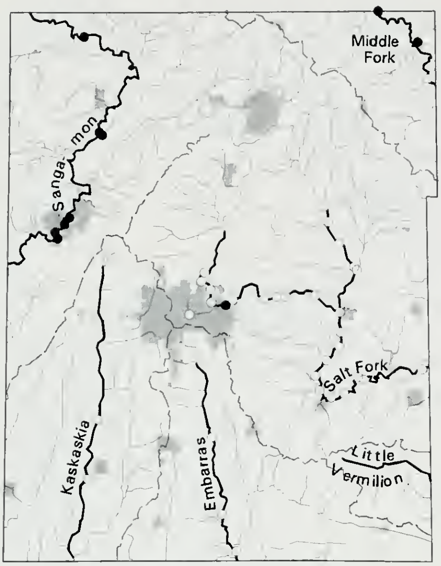
Larimore & Bayley (1987-88)

Lythrurus umbratilis, redfin shiner

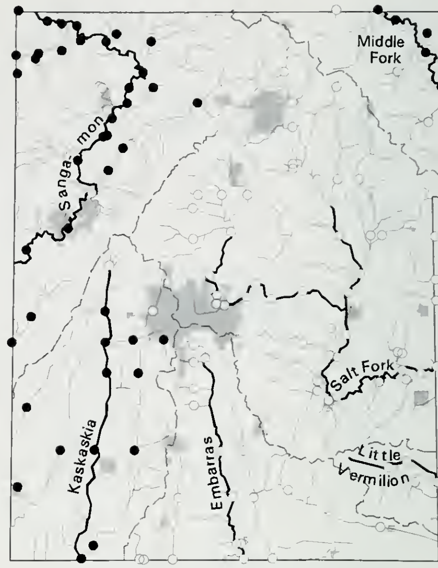
○ = species absent

● = species present

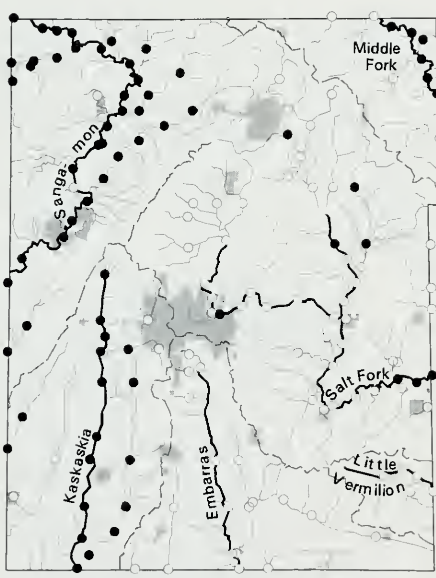
Figure 12



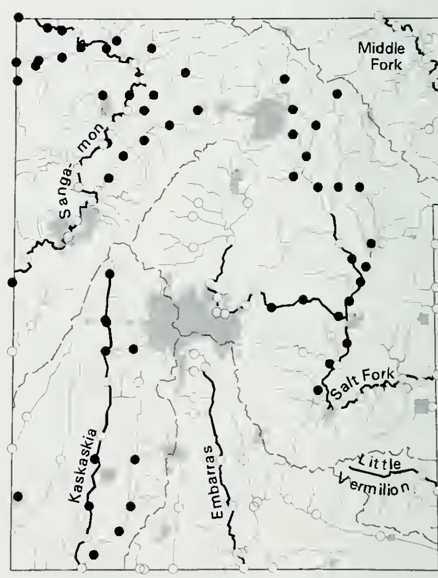
Forbes & Richardson (1889-91)



Thompson & Hunt (1928-29)



Larimore & Smith (1959-60)



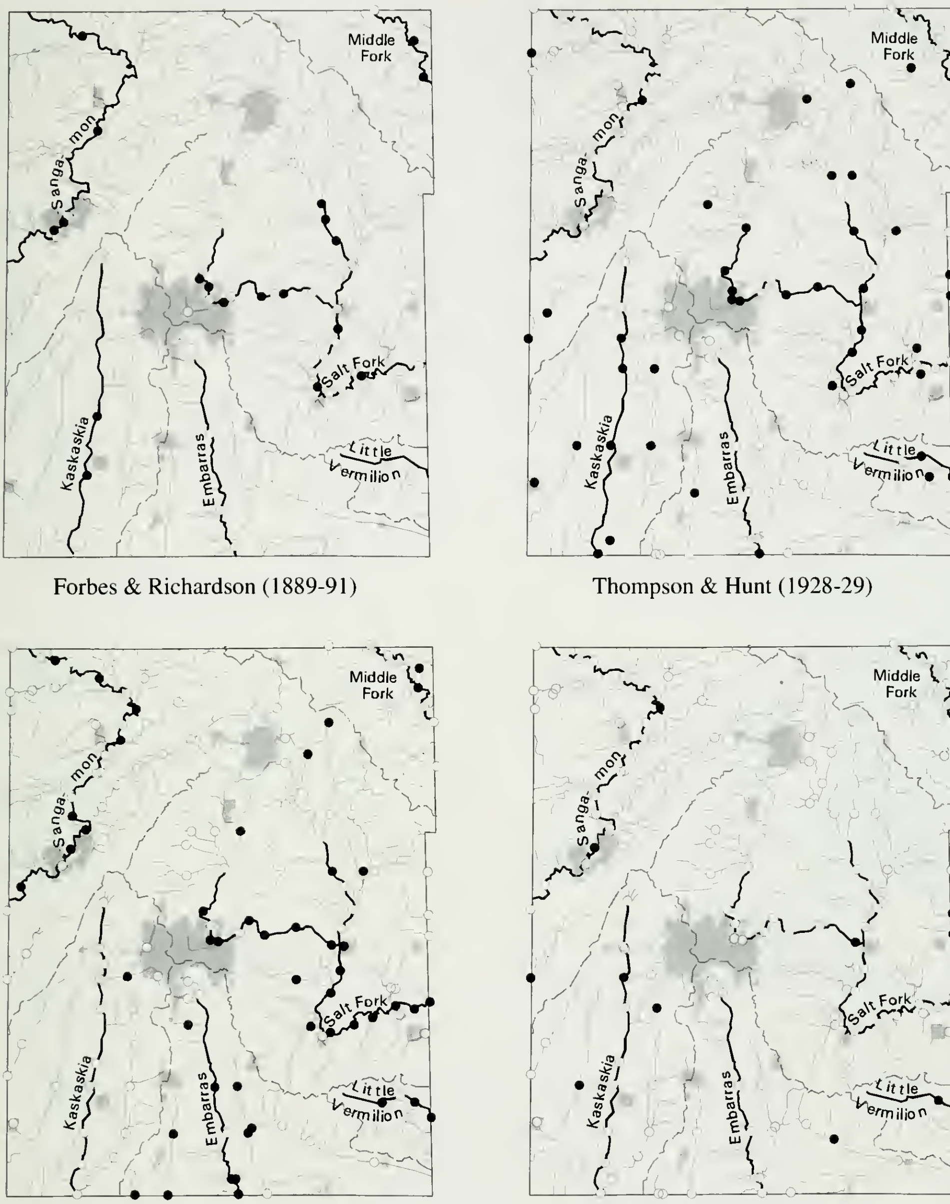
Larimore & Bayley (1987-88)

***Nocomis biguttatus*, hornyhead chub**

○ = species absent

● = species present

Figure 13



Forbes & Richardson (1889-91)

Thompson & Hunt (1928-29)

Larimore & Smith (1959-60)

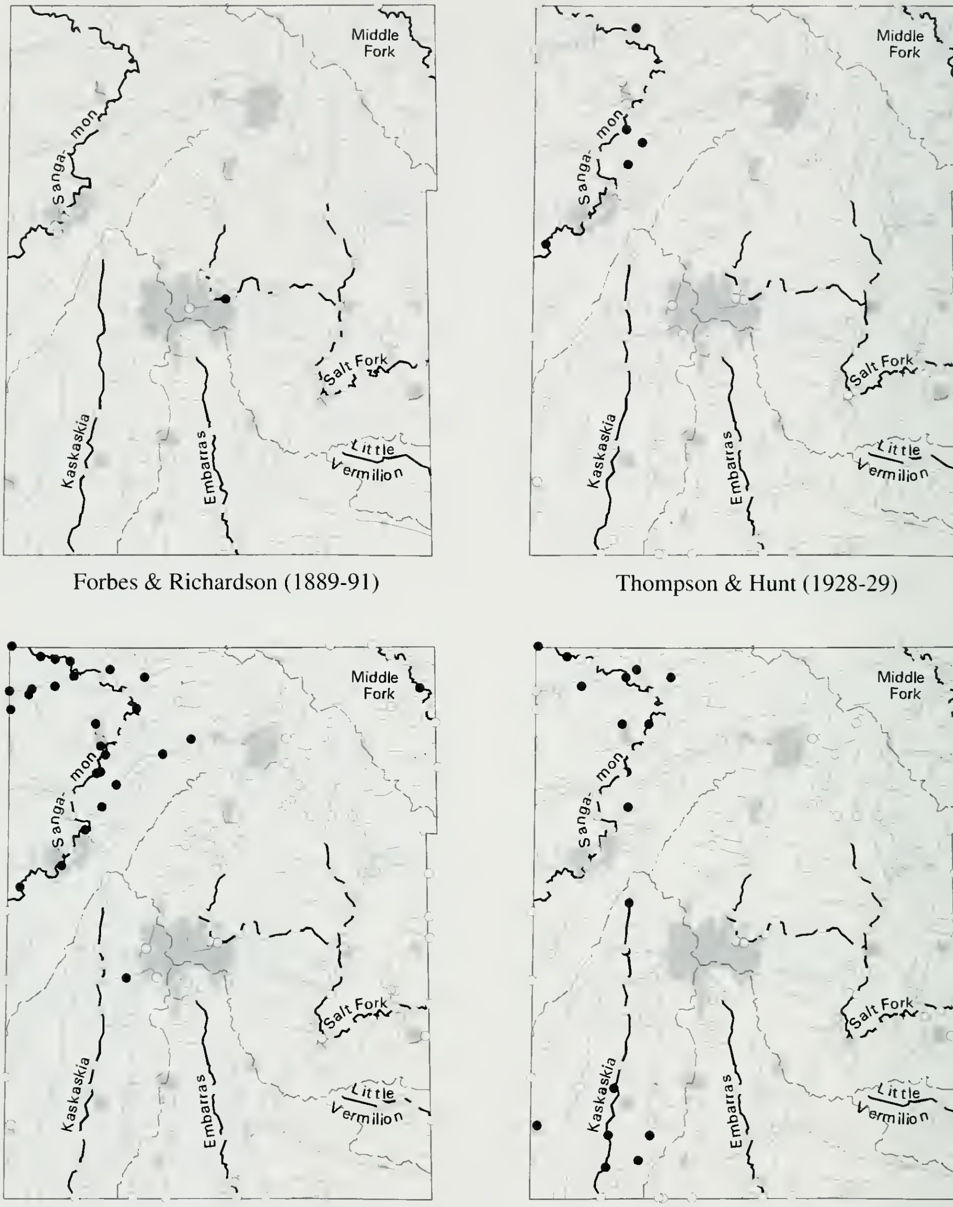
Larimore & Bayley (1987-88)

***Notemigonus crysoleucas*, golden shiner**

○ = species absent

● = species present

Figure 14



Forbes & Richardson (1889-91)

Thompson & Hunt (1928-29)

Larimore & Smith (1959-60)

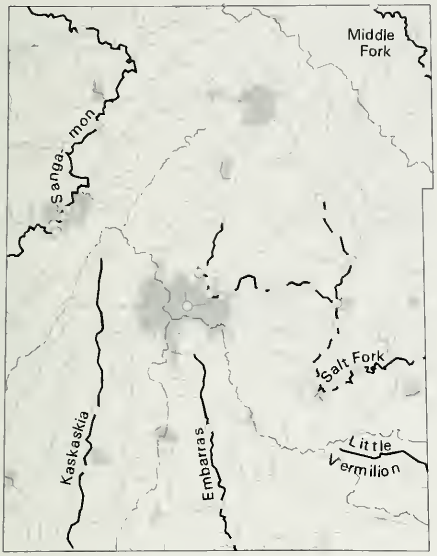
Larimore & Bayley (1987-88)

Notropis dorsalis, bigmouth shiner

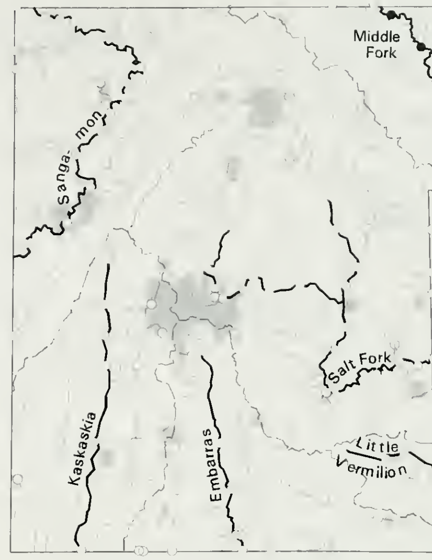
○ = species absent

● = species present

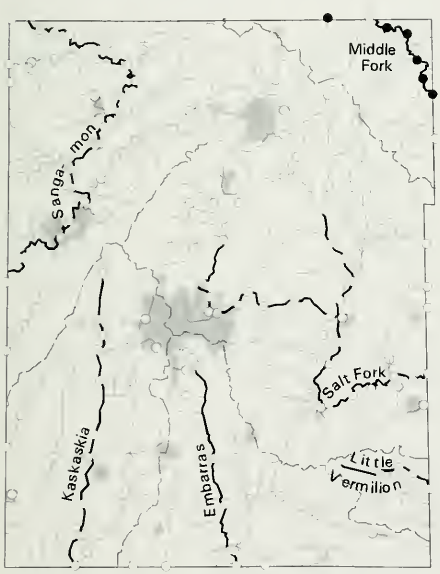
Figure 15



Forbes & Richardson (1889-91)



Thompson & Hunt (1928-29)



Larimore & Smith (1959-60)

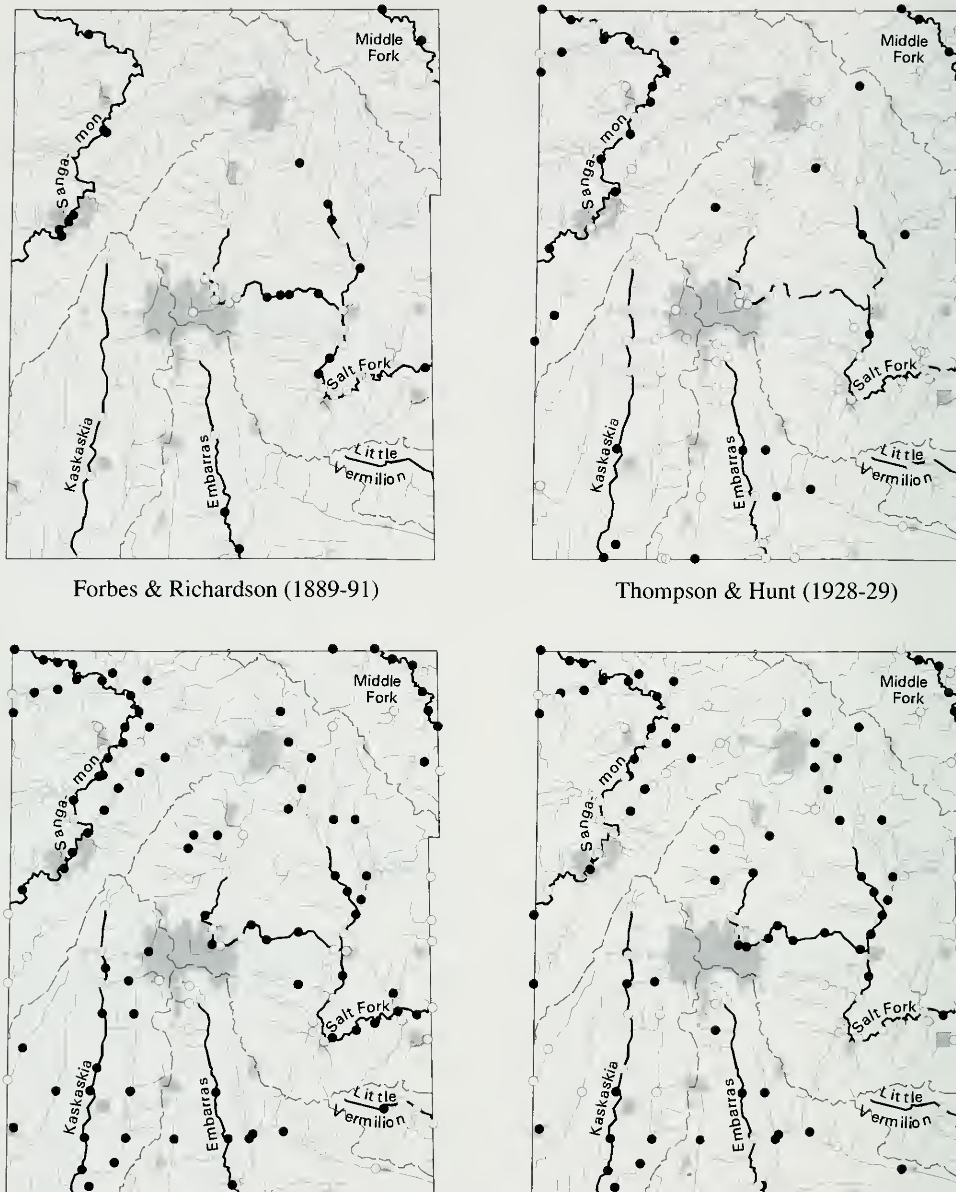
Larimore & Bayley (1987-88)

Notropis rubellus, rosyface shiner

○ = species absent

● = species present

Figure 16



Forbes & Richardson (1889-91)

Thompson & Hunt (1928-29)

Larimore & Smith (1959-60)

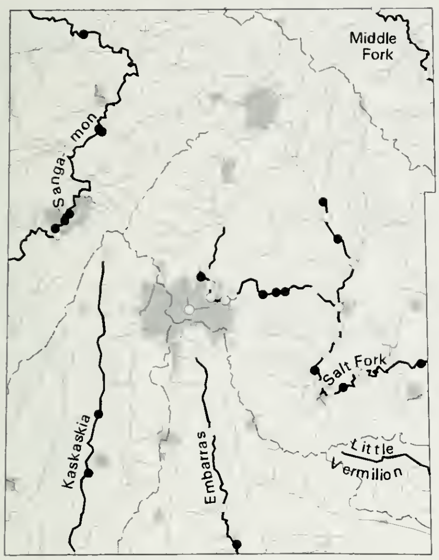
Larimore & Bayley (1987-88)

***Notropis stramineus*, sand shiner**

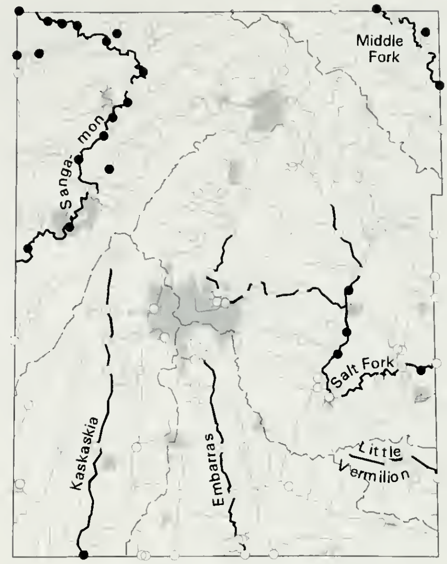
○ = species absent

● = species present

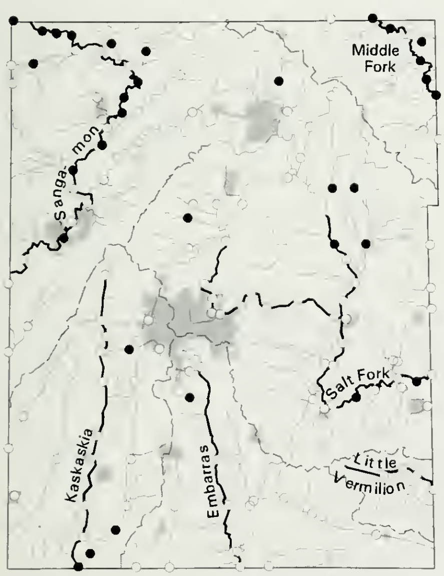
Figure 17



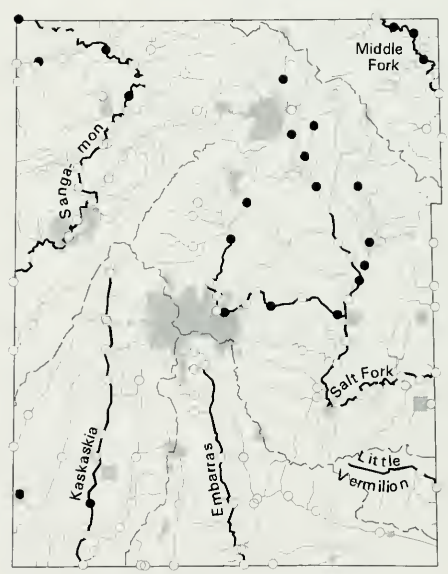
Forbes & Richardson (1889-91)



Thompson & Hunt (1928-29)



Larimore & Smith (1959-60)



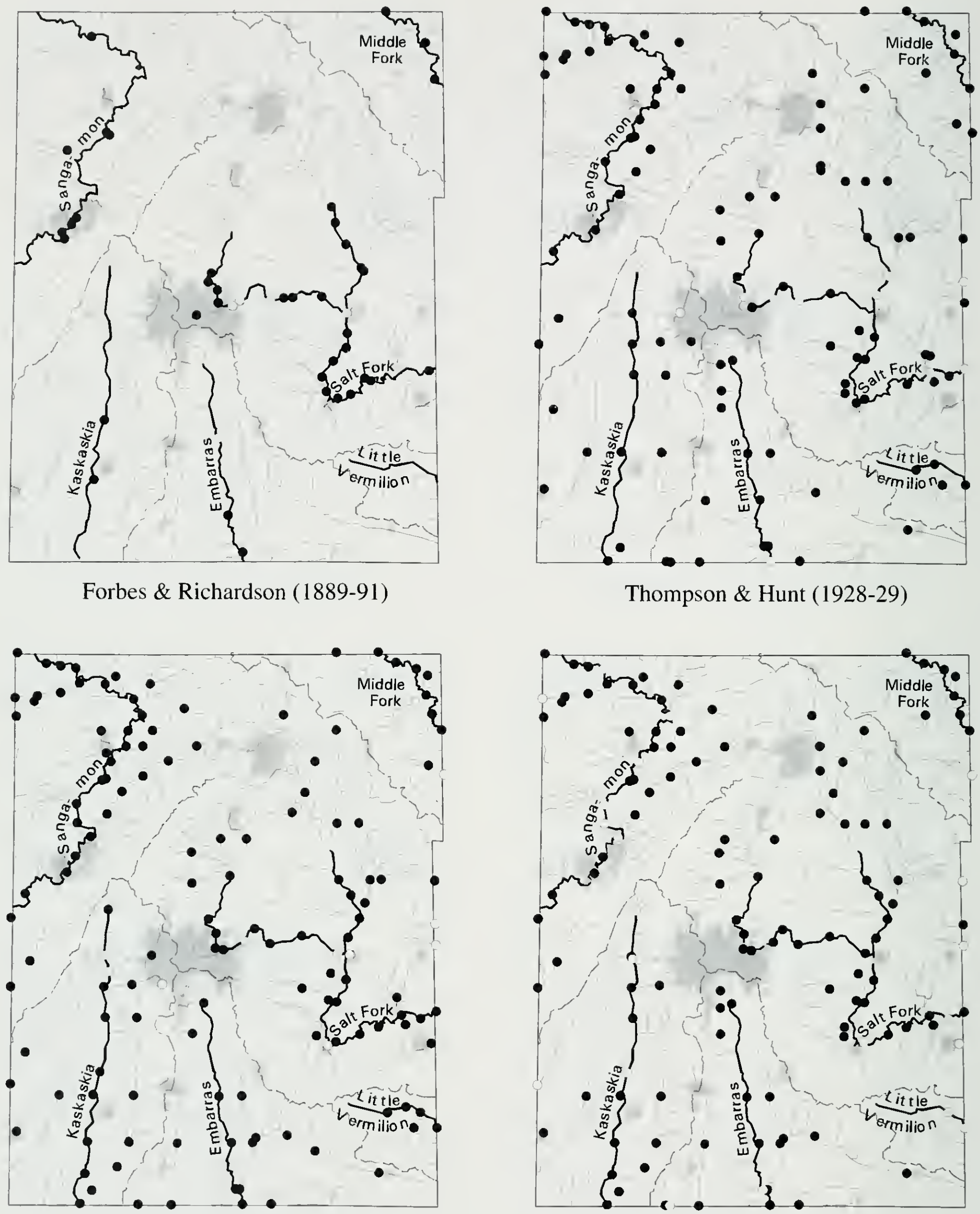
Larimore & Bayley (1987-88)

***Phenacobius mirabilis*, suckermouth minnow**

○ = species absent

● = species present

Figure 18



Forbes & Richardson (1889-91)

Thompson & Hunt (1928-29)

Larimore & Smith (1959-60)

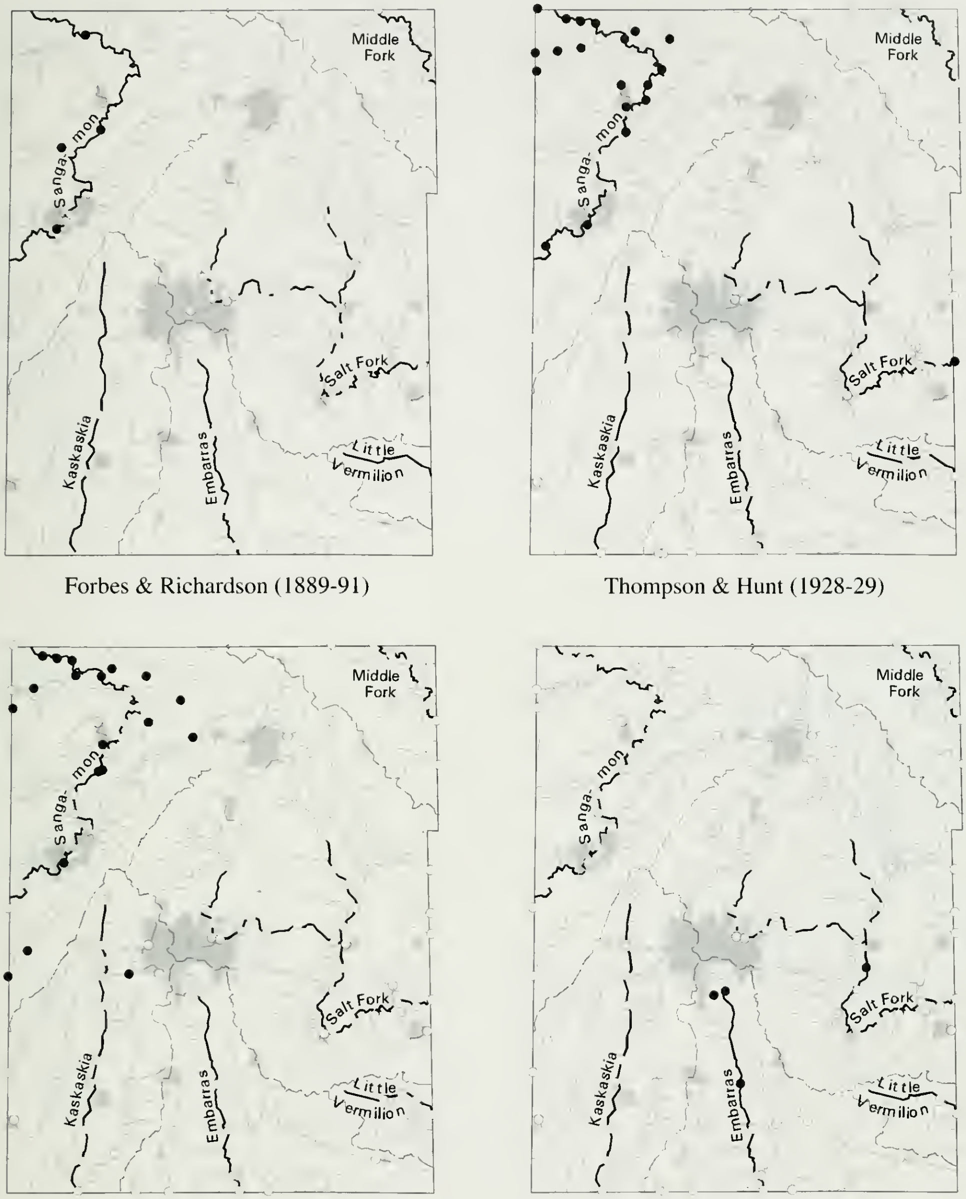
Larimore & Bayley (1987-88)

***Pimephales notatus*, bluntnose minnow**

○ = species absent

● = species present

Figure 19



Forbes & Richardson (1889-91)

Thompson & Hunt (1928-29)

Larimore & Smith (1959-60)

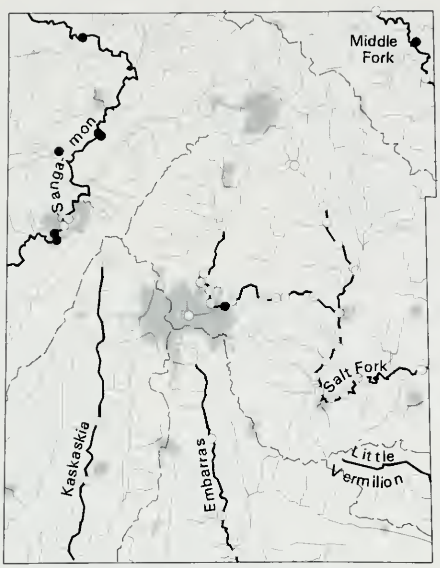
Larimore & Bayley (1987-88)

***Pimephales promelas*, fathead minnow**

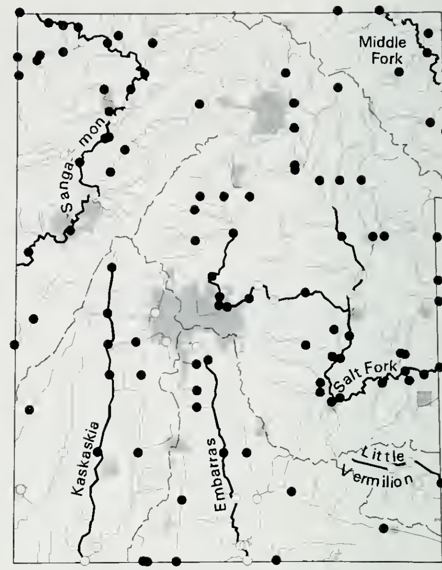
○ = species absent

● = species present

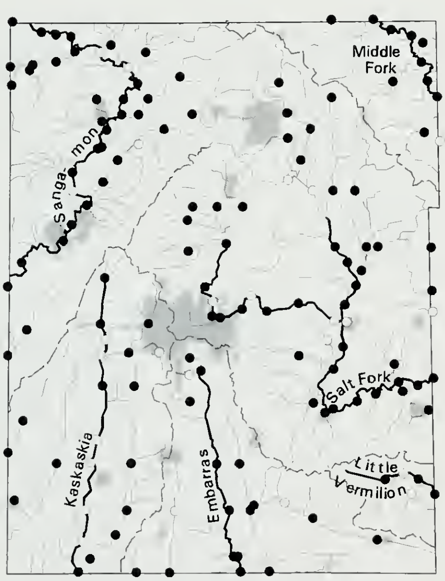
Figure 20



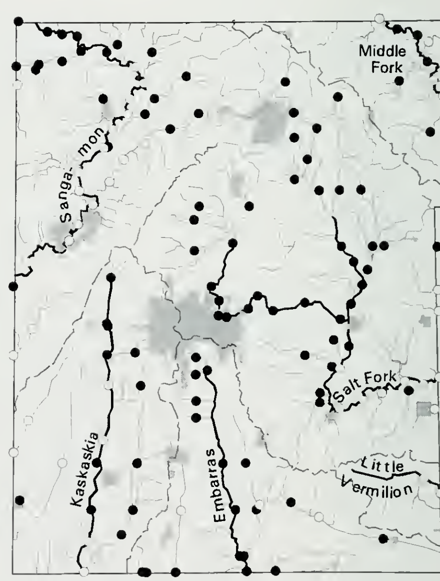
Forbes & Richardson (1889-91)



Thompson & Hunt (1928-29)



Larimore & Smith (1959-60)



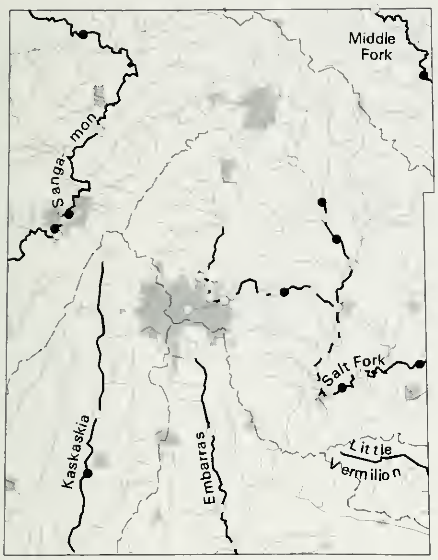
Larimore & Bayley (1987-88)

***Semotilus atromaculatus*, creek chub**

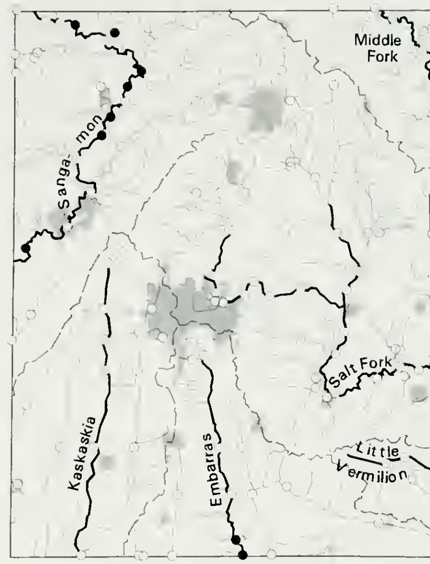
○ = species absent

● = species present

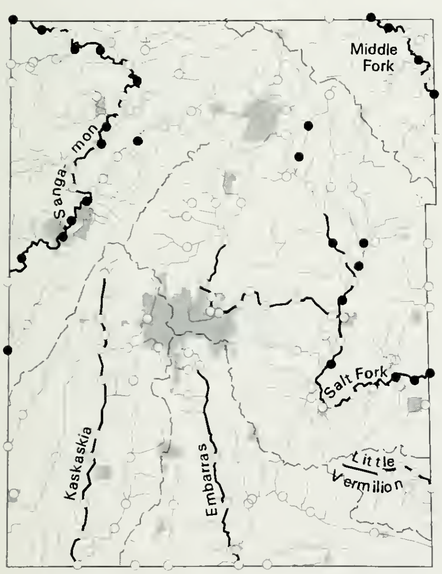
Figure 21



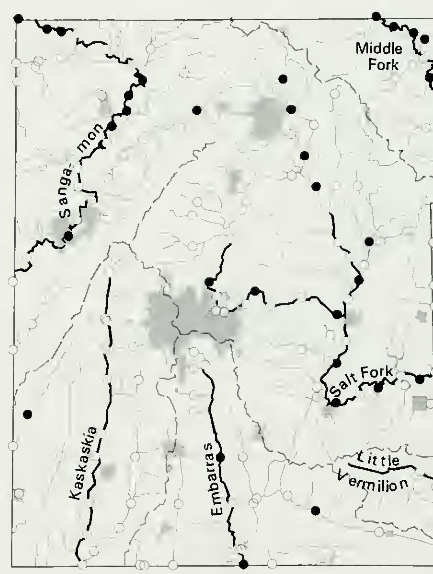
Forbes & Richardson (1889-91)



Thompson & Hunt (1928-29)



Larimore & Smith (1959-60)



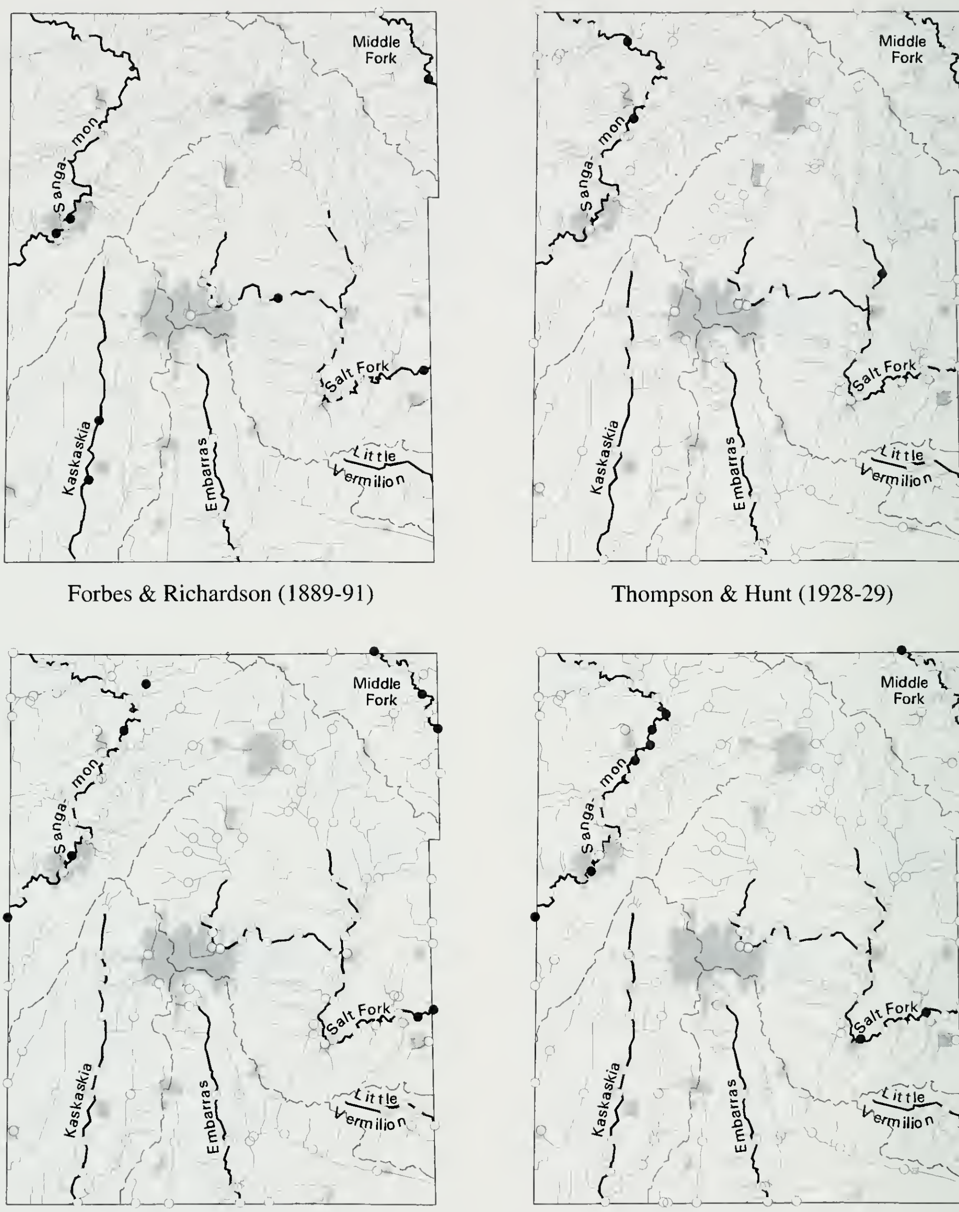
Larimore & Bayley (1987-88)

Carpoides cyprinus, quillback

○ = species absent

● = species present

Figure 22



Forbes & Richardson (1889-91)

Thompson & Hunt (1928-29)

Larimore & Smith (1959-60)

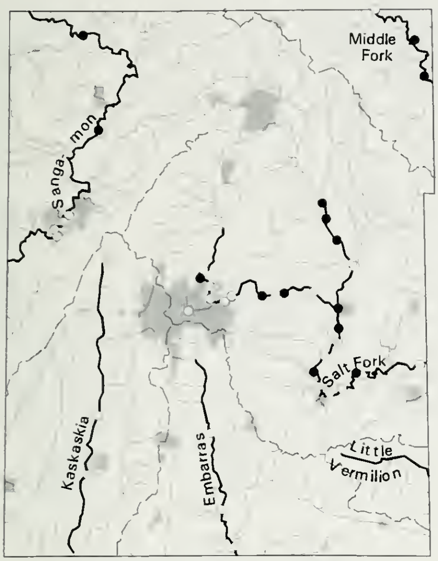
Larimore & Bayley (1987-88)

Carpoides velifer, highfin carpsucker

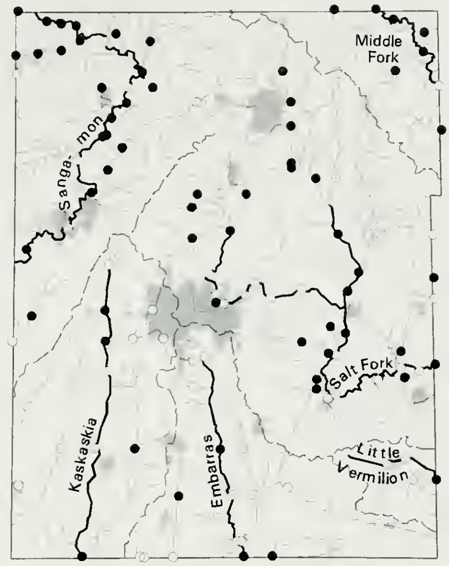
○ = species absent

● = species present

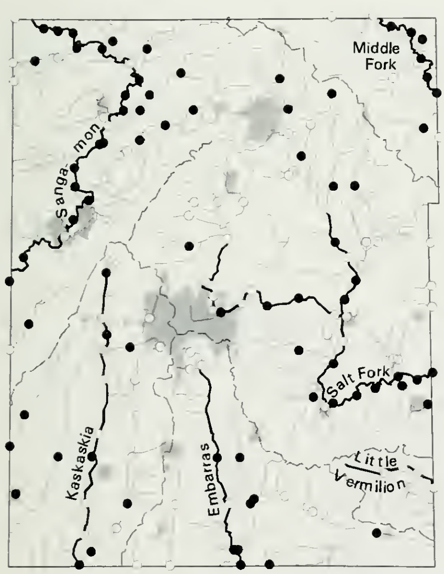
Figure 23



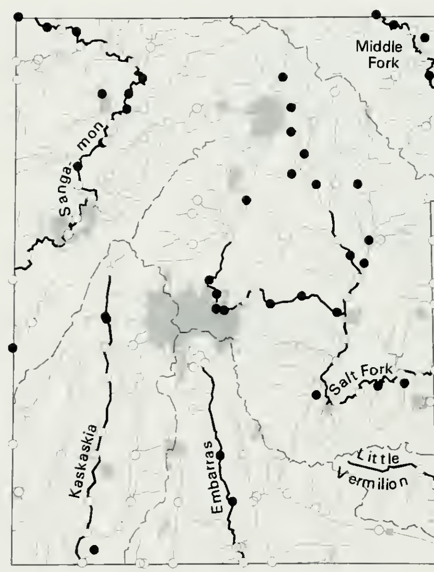
Forbes & Richardson (1889-91)



Thompson & Hunt (1928-29)



Larimore & Smith (1959-60)



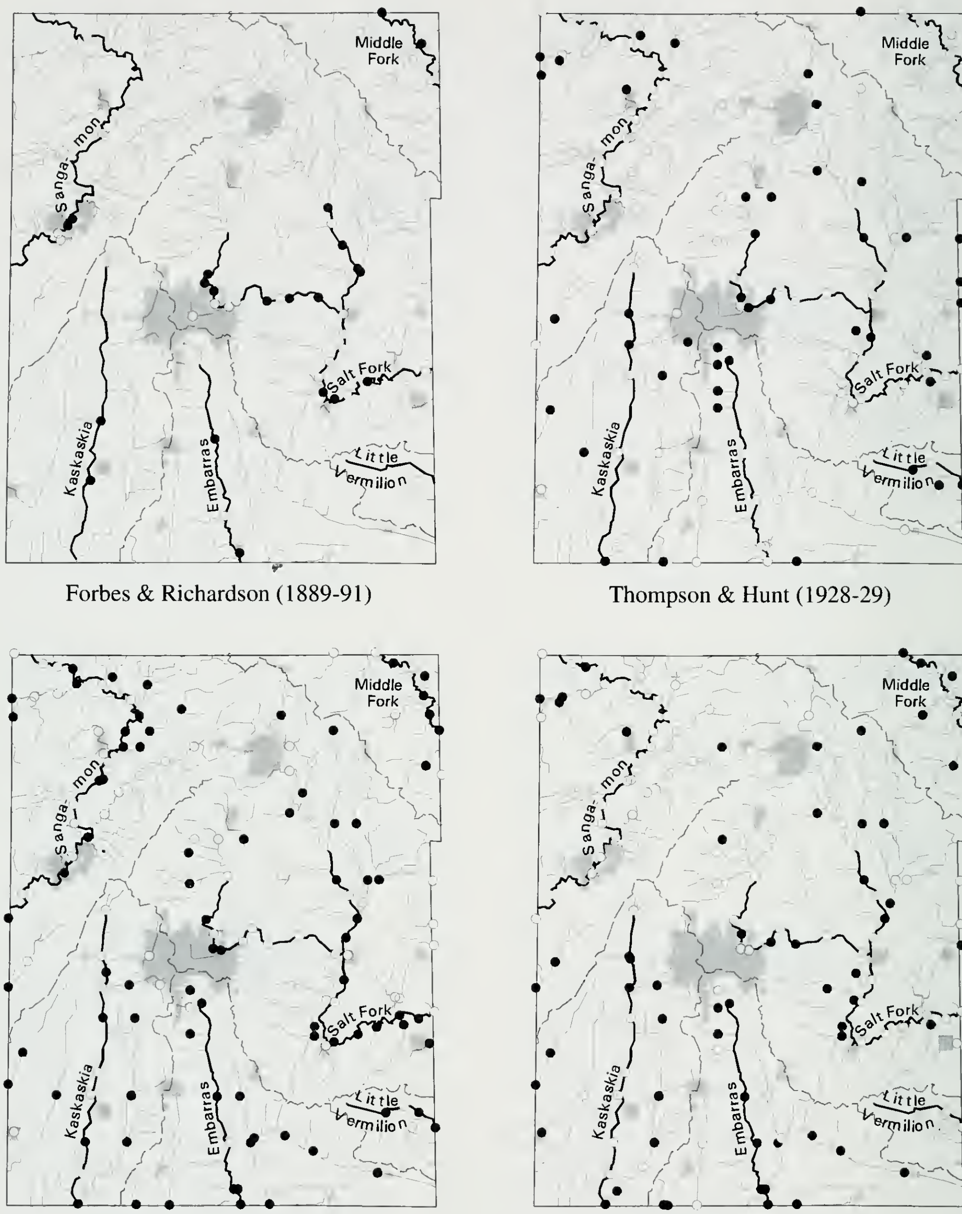
Larimore & Bayley (1987-88)

***Catostomus commersoni*, white sucker**

○ = species absent

● = species present

Figure 24



Forbes & Richardson (1889-91)

Thompson & Hunt (1928-29)

Larimore & Smith (1959-60)

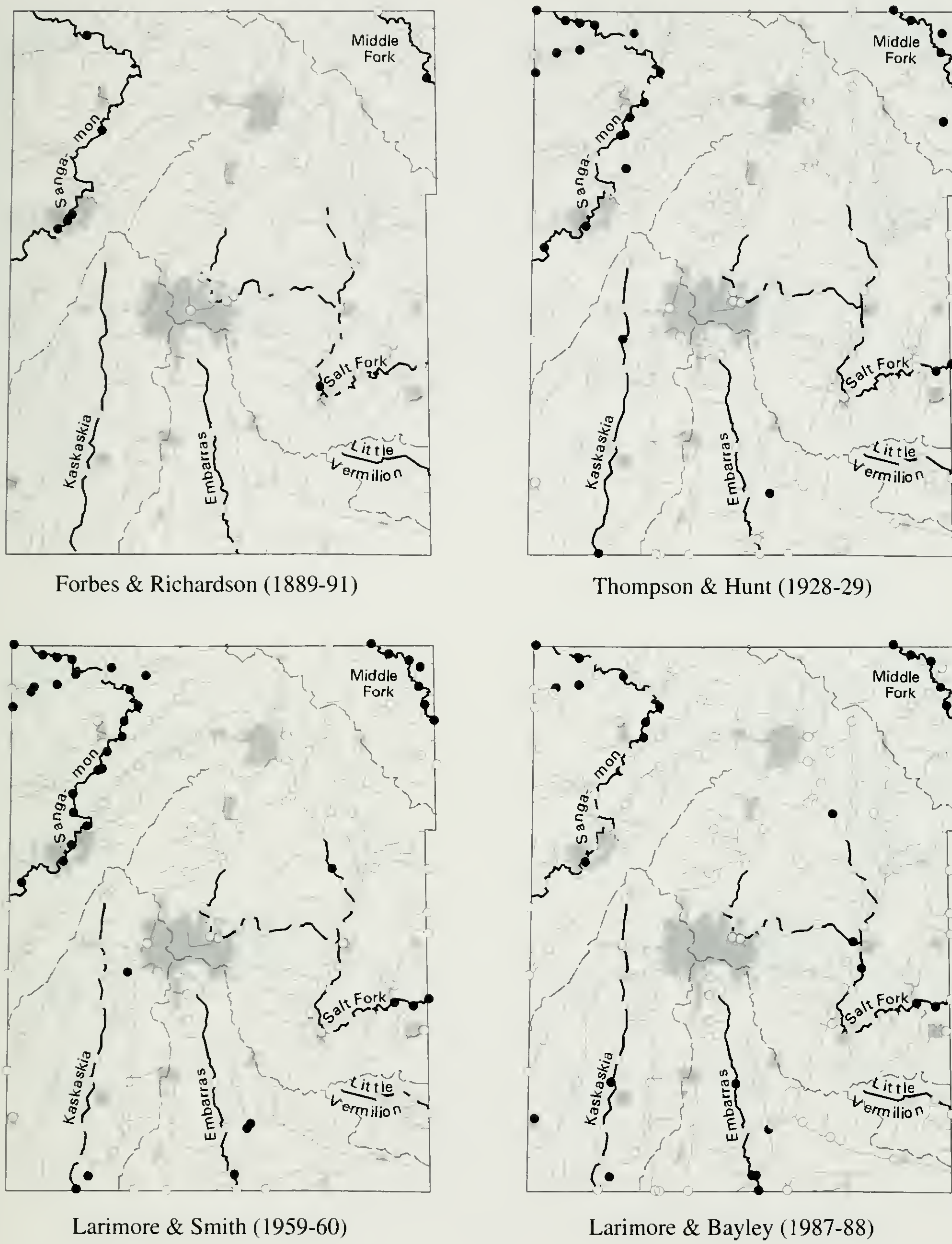
Larimore & Bayley (1987-88)

***Erimyzon oblongus*, creek chubsucker**

○ = species absent

● = species present

Figure 25

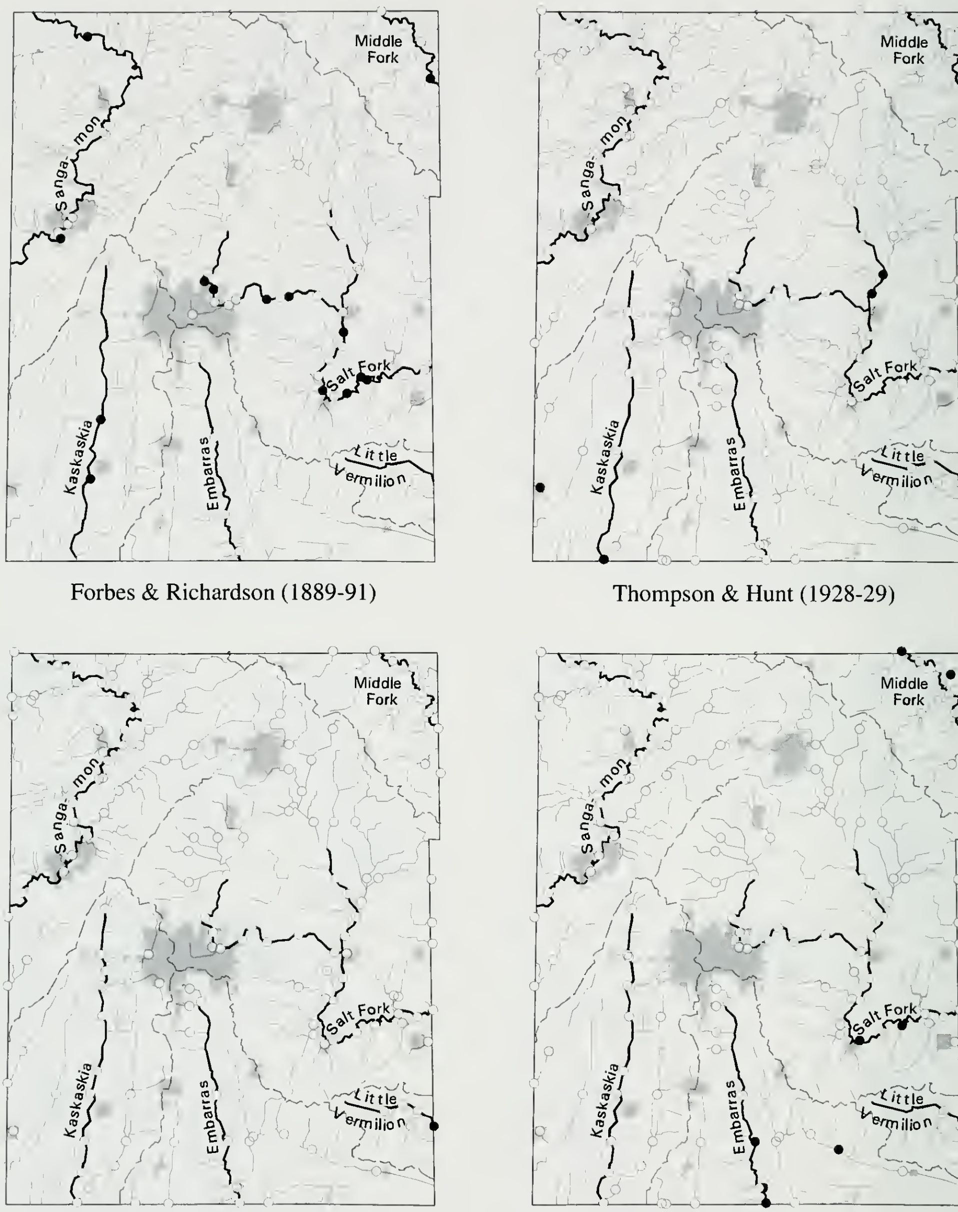


***Hypentelium nigricans*, northern hogsucker**

○ = species absent

● = species present

Figure 26



Forbes & Richardson (1889-91)

Thompson & Hunt (1928-29)

Larimore & Smith (1959-60)

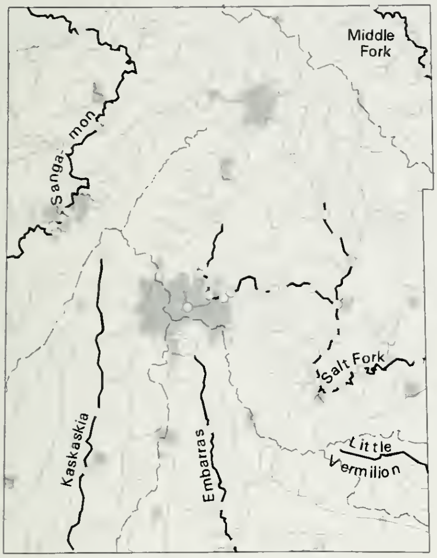
Larimore & Bayley (1987-88)

***Minytrema melanops*, spotted sucker**

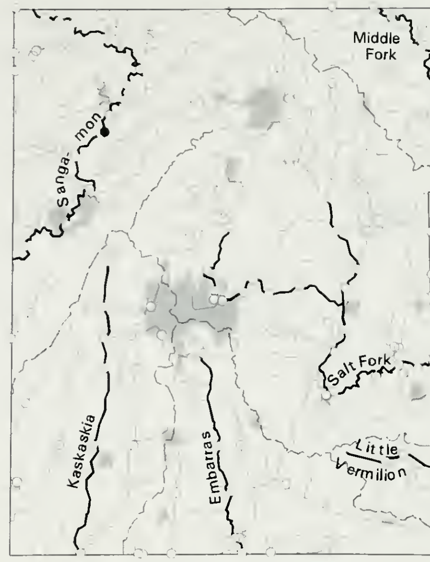
○ = species absent

● = species present

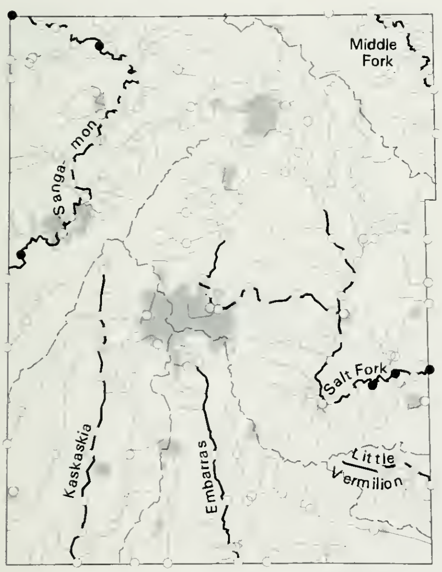
Figure 27



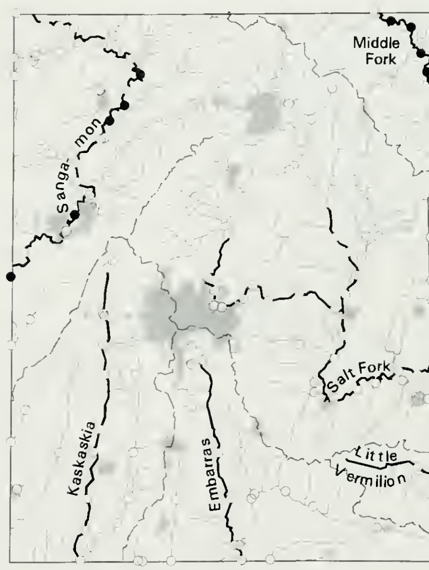
Forbes & Richardson (1889-91)



Thompson & Hunt (1928-29)



Larimore & Smith (1959-60)



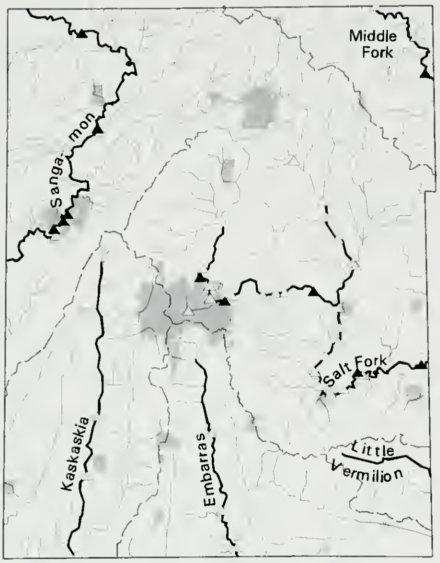
Larimore & Bayley (1987-88)

***Moxostoma anisurum*, silver redhorse**

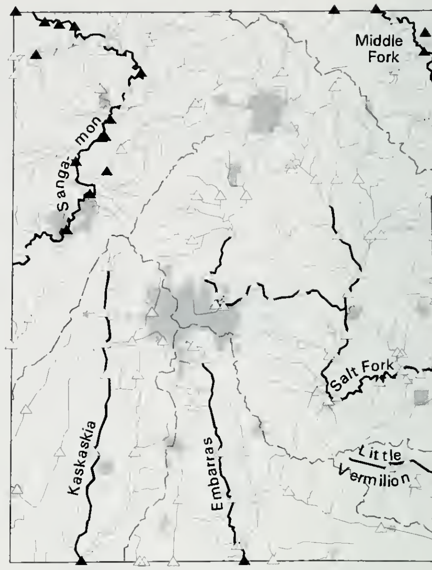
○ = species absent

● = species present

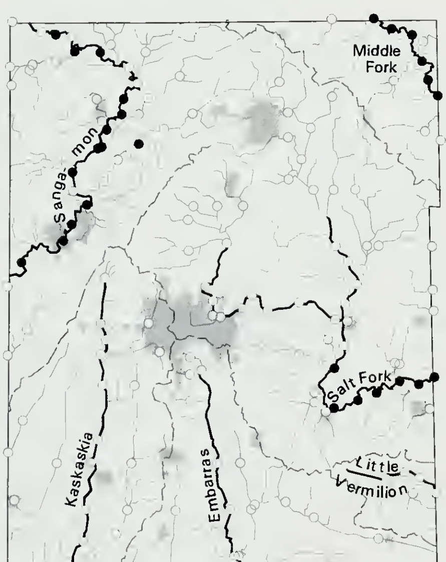
Figure 28



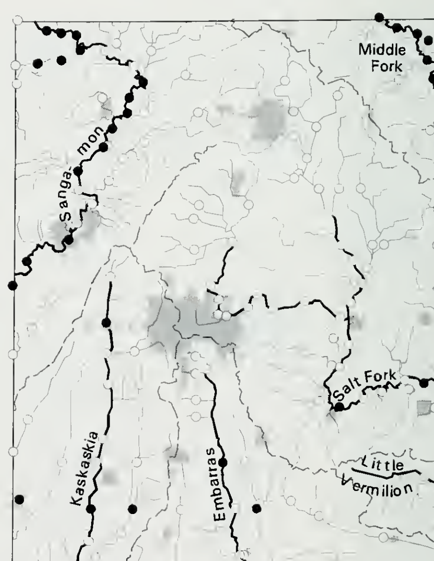
Forbes & Richardson (1889-91)



Thompson & Hunt (1928-29)



Larimore & Smith (1959-60)



Larimore & Bayley (1987-88)

***Moxostoma erythrurum*, golden redhorse**

Composite with *M. duquesnei*, black redhorse

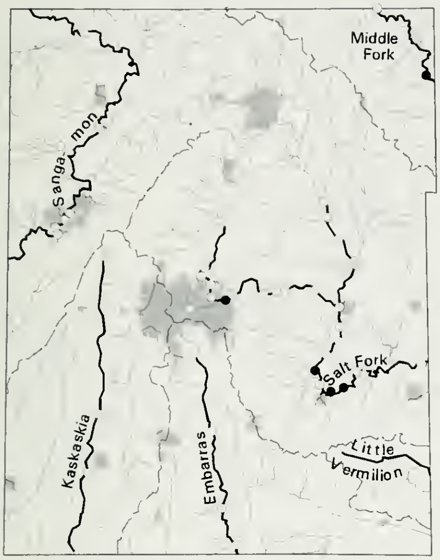
○ = species absent

● = species present

△ = composite absent

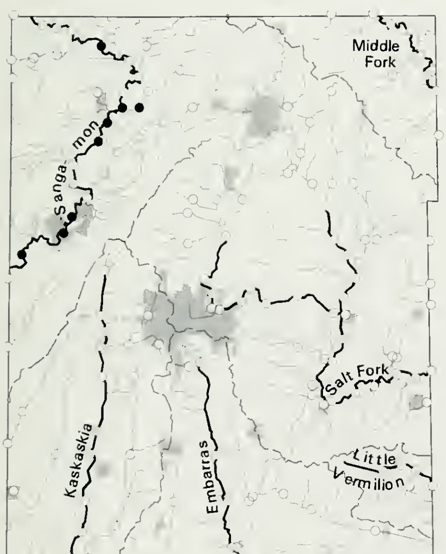
▲ = composite present

Figure 29

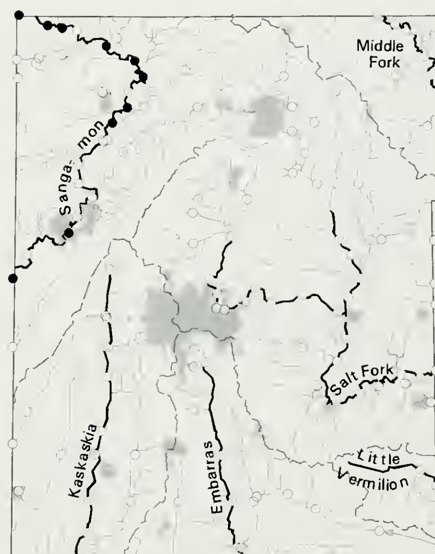


Forbes & Richardson (1889-91)

Thompson & Hunt (1928-29)



Larimore & Smith (1959-60)



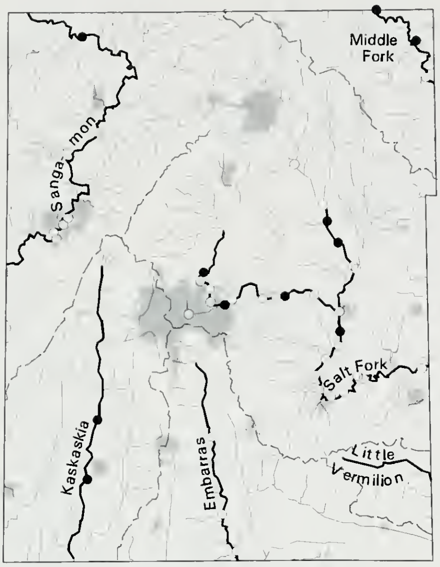
Larimore & Bayley (1987-88)

Moxostoma macrolepidotum, shorthead redhorse

○ = species absent

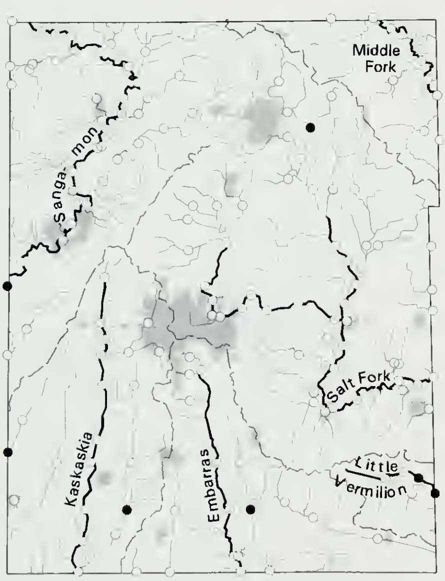
● = species present

Figure 30



Forbes & Richardson (1889-91)

Thompson & Hunt (1928-29)



Larimore & Smith (1959-60)

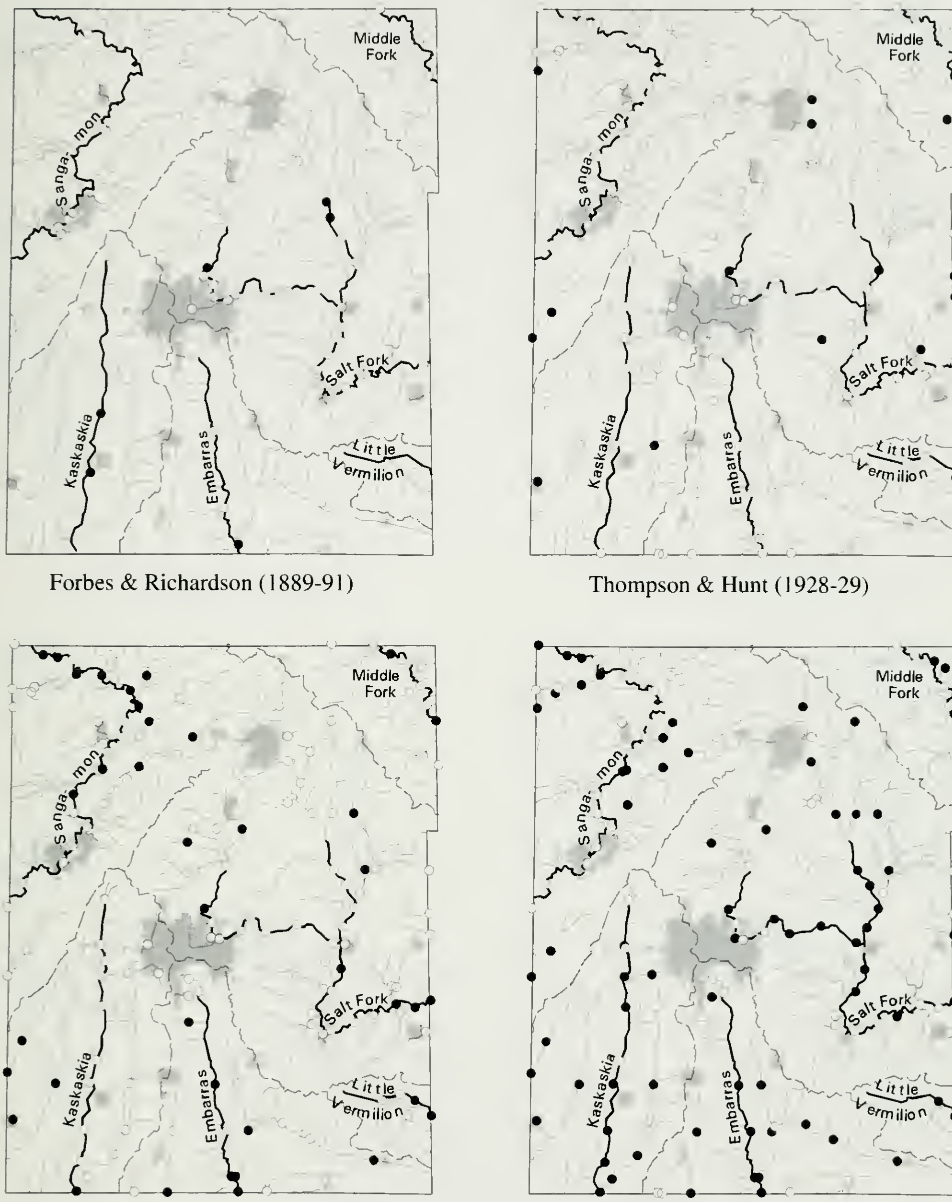
Larimore & Bayley (1987-88)

Ameiurus melas, black bullhead

○ = species absent

● = species present

Figure 31



Forbes & Richardson (1889-91)

Thompson & Hunt (1928-29)

Larimore & Smith (1959-60)

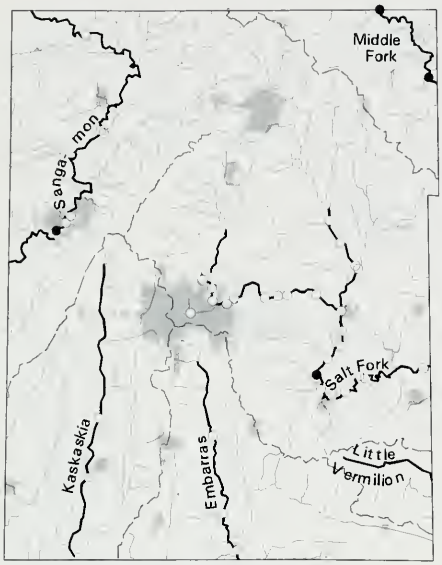
Larimore & Bayley (1987-88)

***Ameiurus natalis,* yellow bullhead**

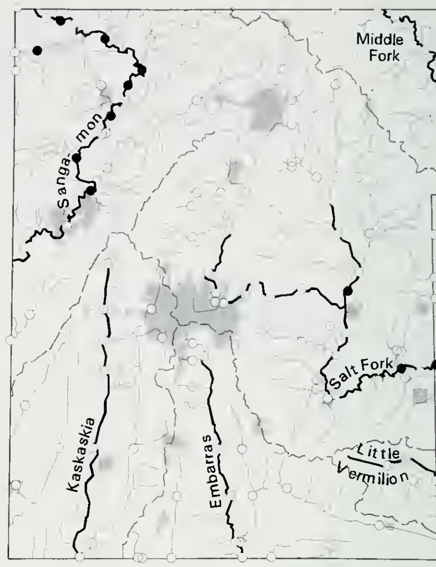
○ = species absent

● = species present

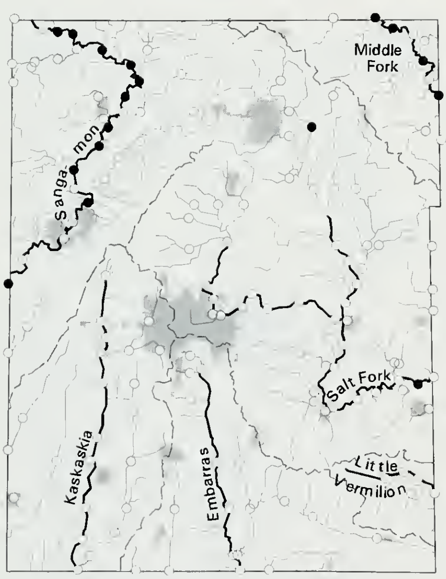
Figure 32



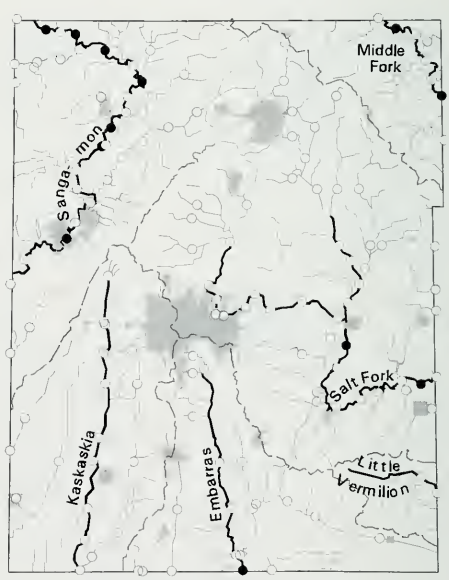
Forbes & Richardson (1889-91)



Thompson & Hunt (1928-29)



Larimore & Smith (1959-60)



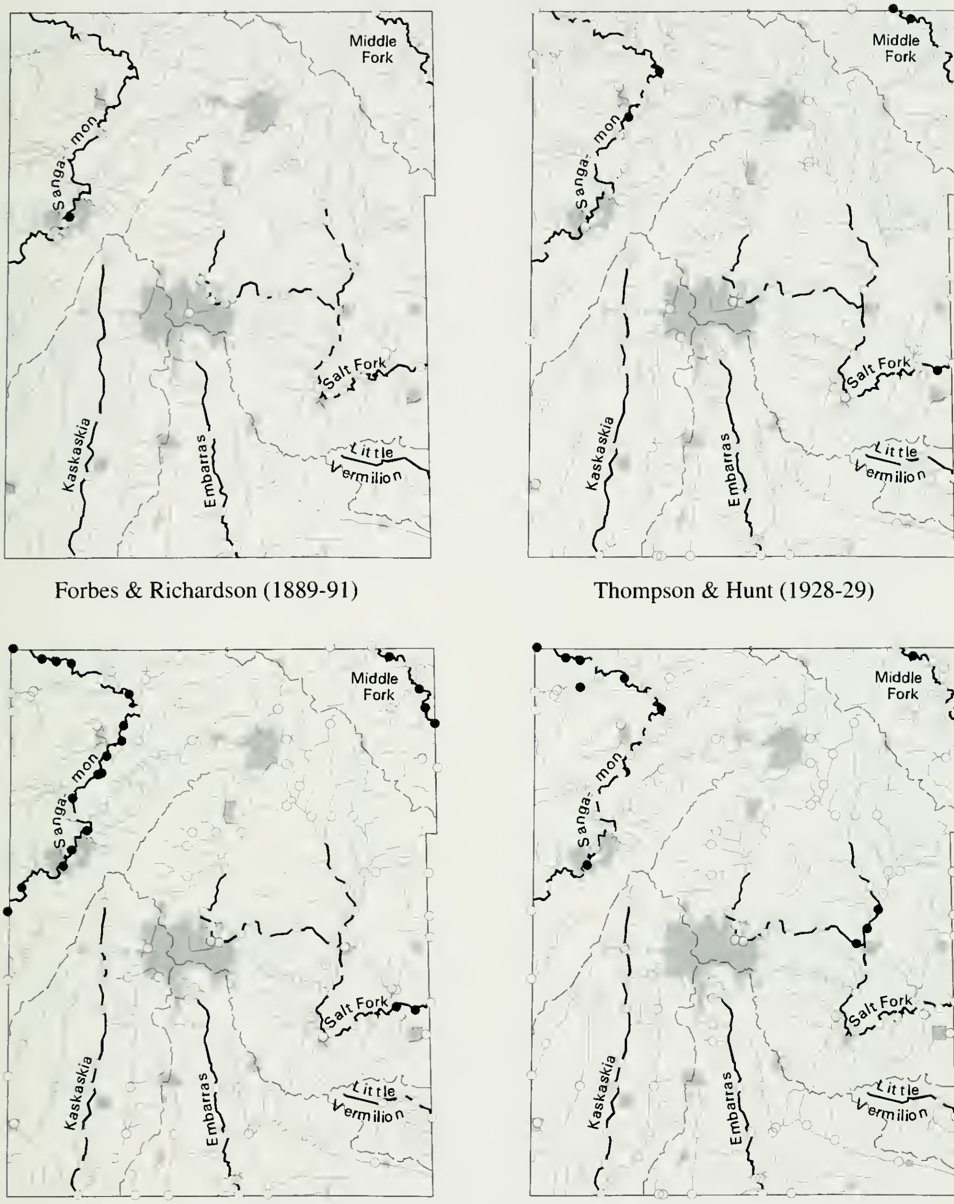
Larimore & Bayley (1987-88)

Ictalurus punctatus, channel catfish

○ = species absent

● = species present

Figure 33



Forbes & Richardson (1889-91)

Thompson & Hunt (1928-29)

Larimore & Smith (1959-60)

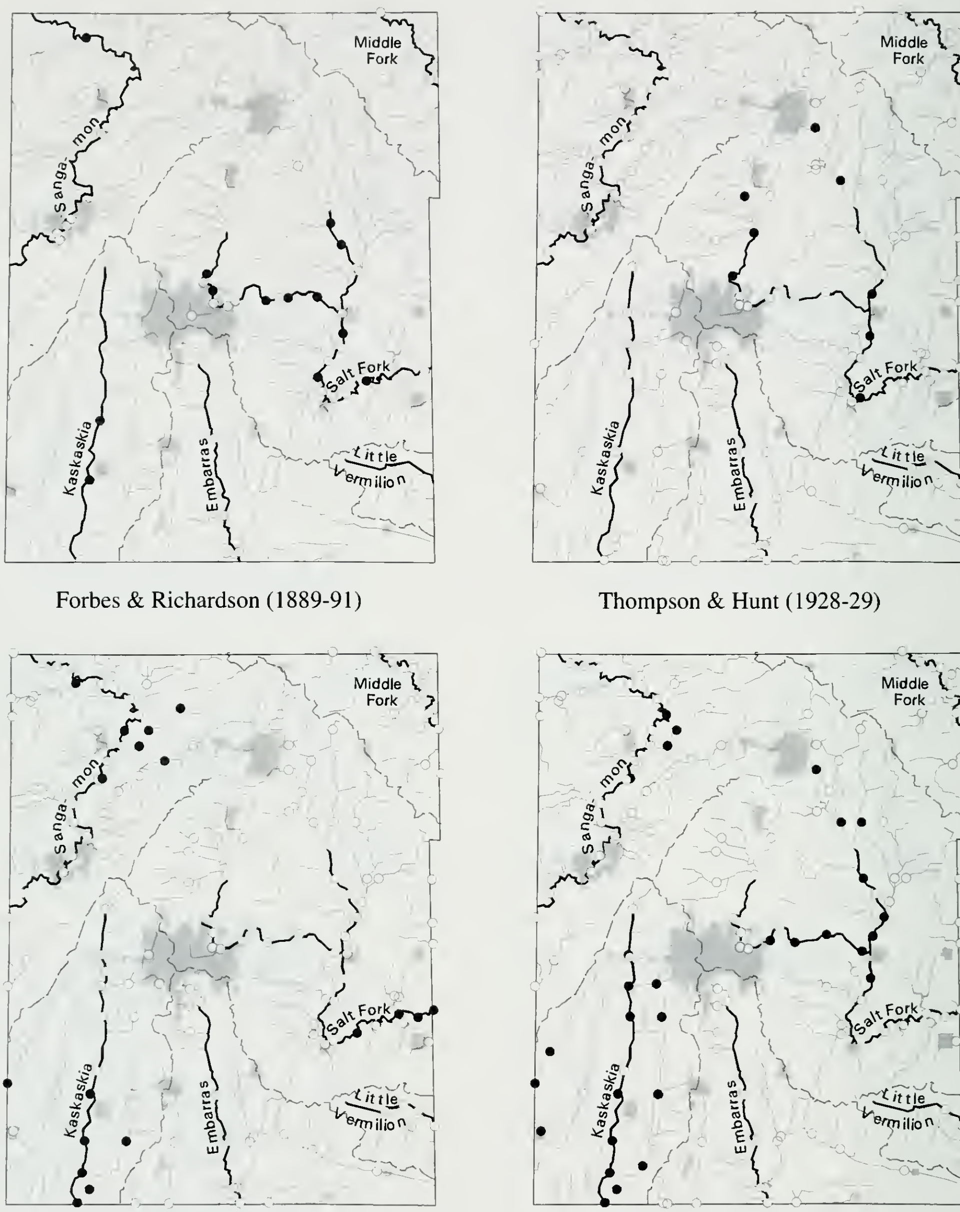
Larimore & Bayley (1987-88)

***Noturus flavus*, stonecat**

○ = species absent

● = species present

Figure 34



Forbes & Richardson (1889-91)

Thompson & Hunt (1928-29)

Larimore & Smith (1959-60)

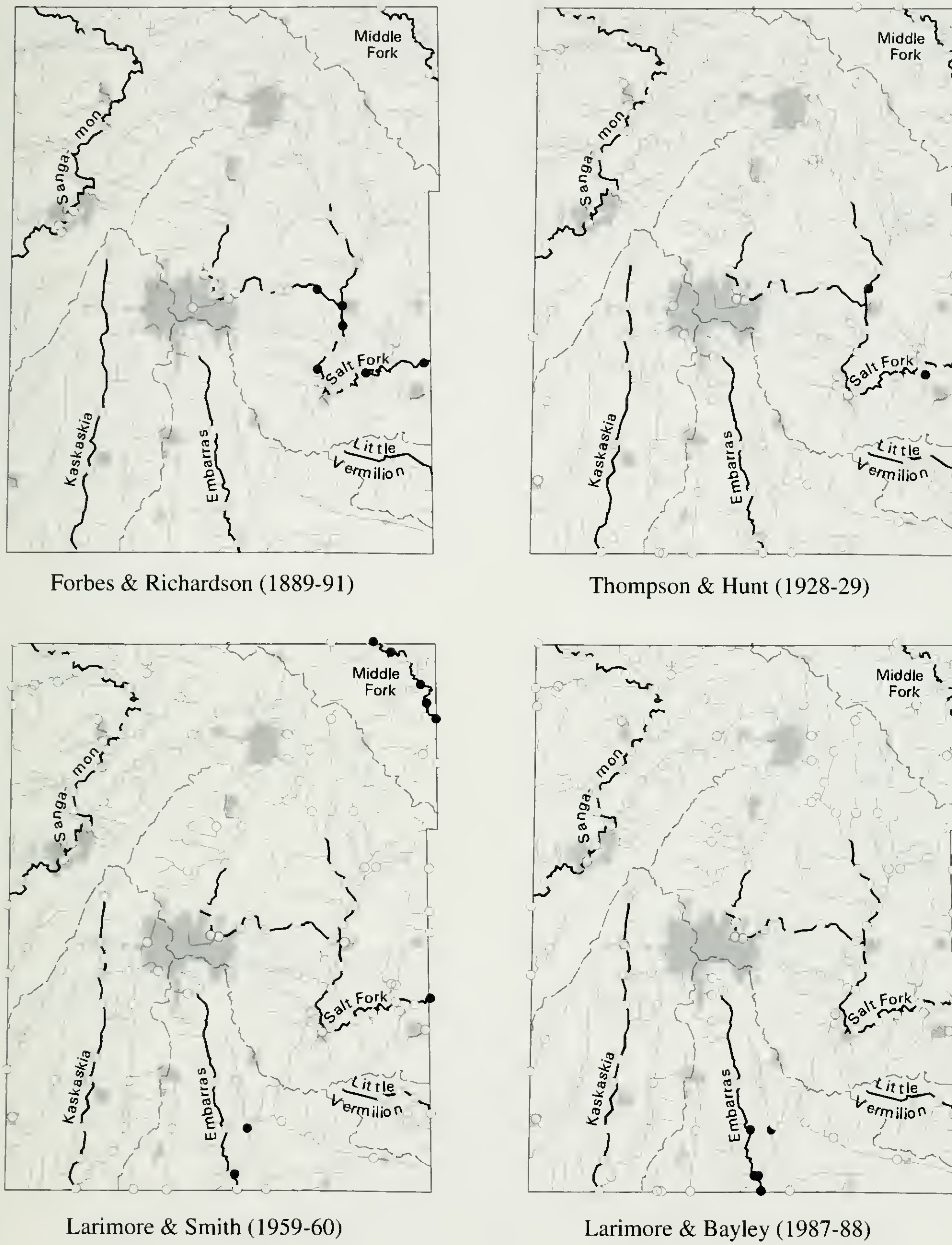
Larimore & Bayley (1987-88)

Noturus gyrinus, tadpole madtom

○ = species absent

● = species present

Figure 35

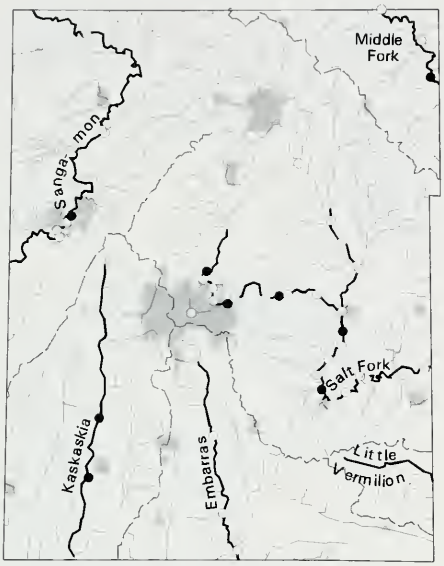


***Noturus miurus*, brindled madtom**

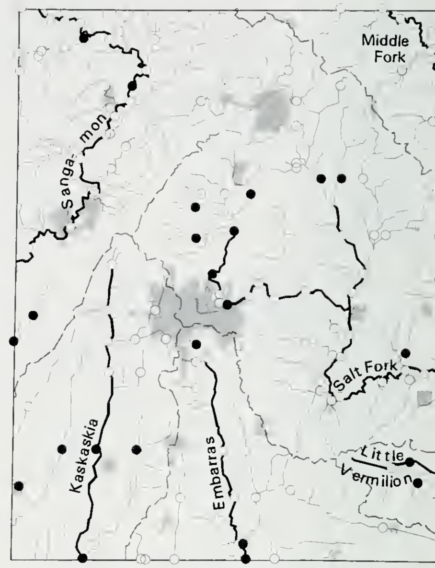
○ = species absent

● = species present

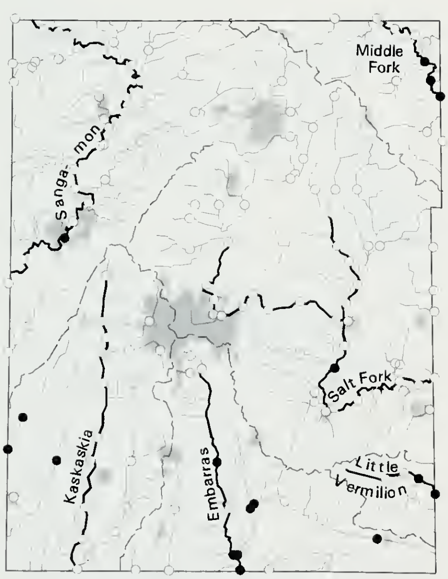
Figure 36



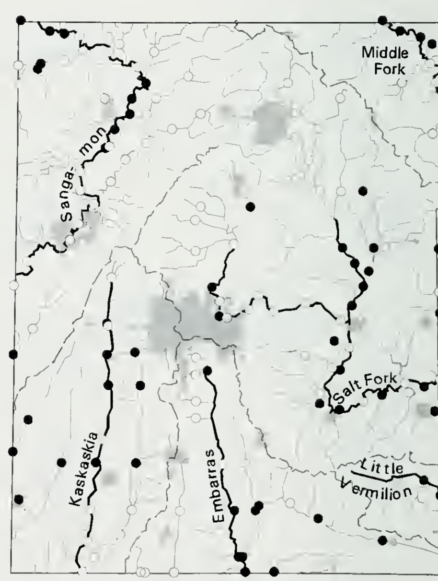
Forbes & Richardson (1889-91)



Thompson & Hunt (1928-29)



Larimore & Smith (1959-60)



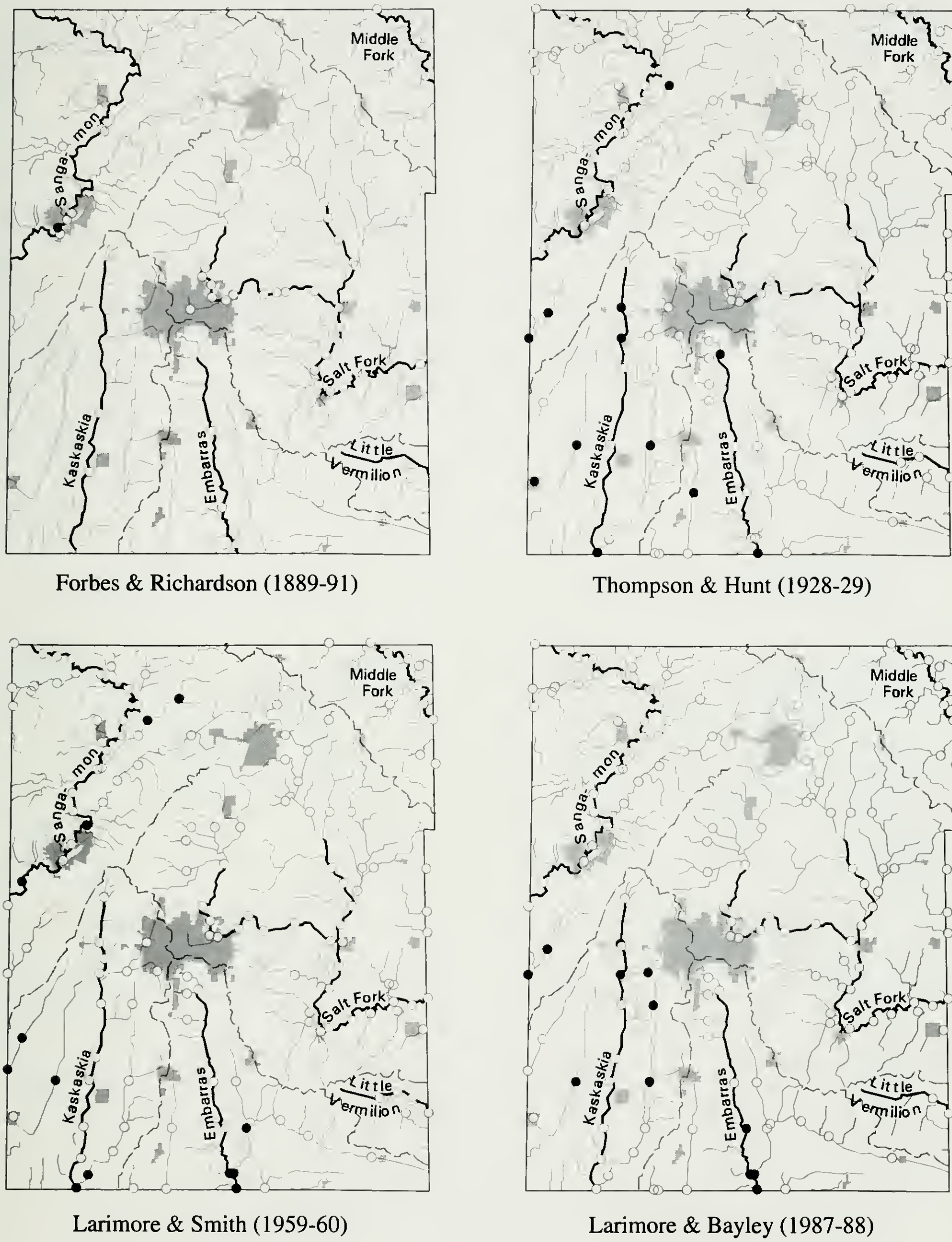
Larimore & Bayley (1987-88)

***Esox americanus*, grass pickerel**

○ = species absent

● = species present

Figure 37

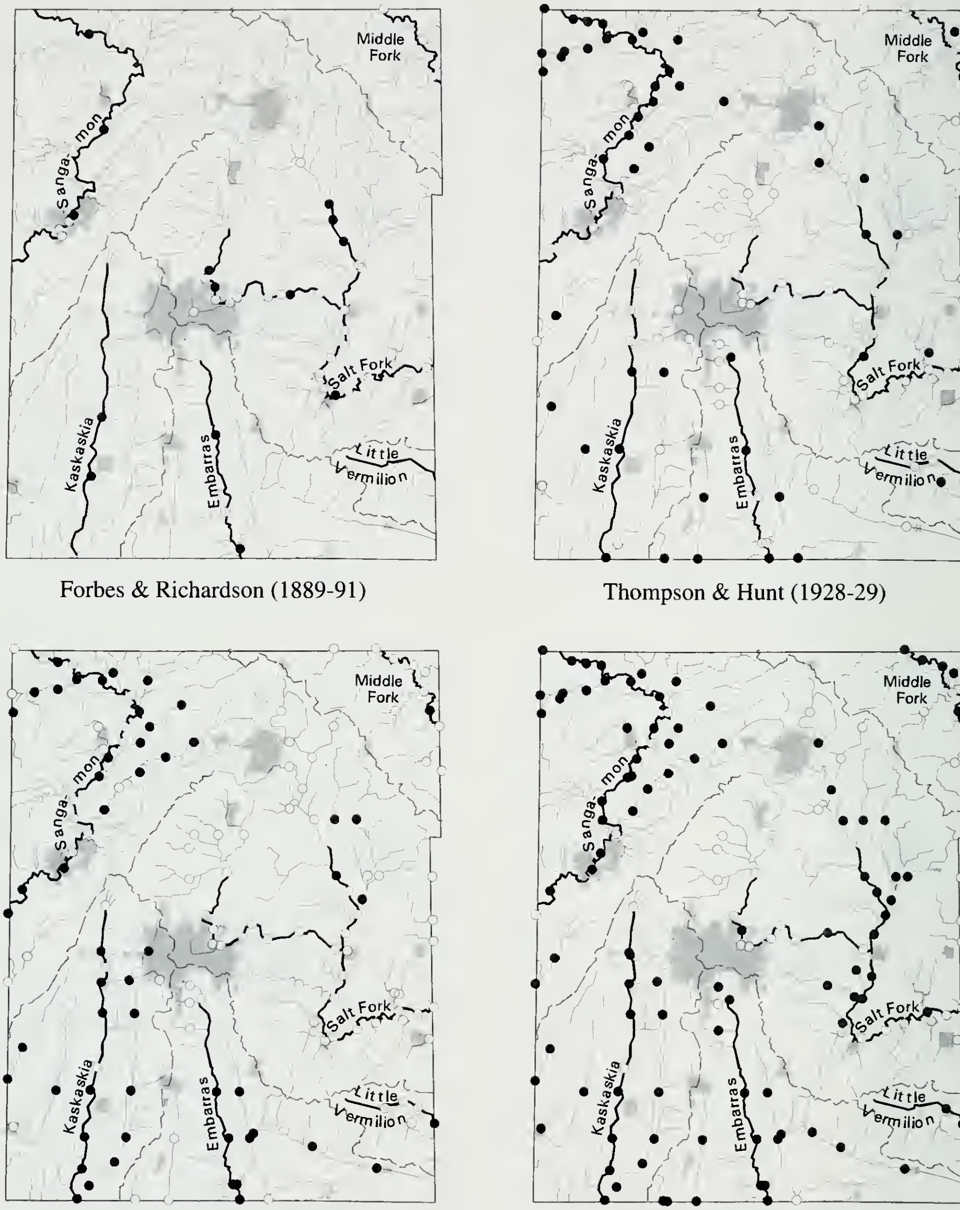


***Aphredoderus sayanus*, pirate perch**

○ = species absent

● = species present

Figure 38



Forbes & Richardson (1889-91)

Thompson & Hunt (1928-29)

Larimore & Smith (1959-60)

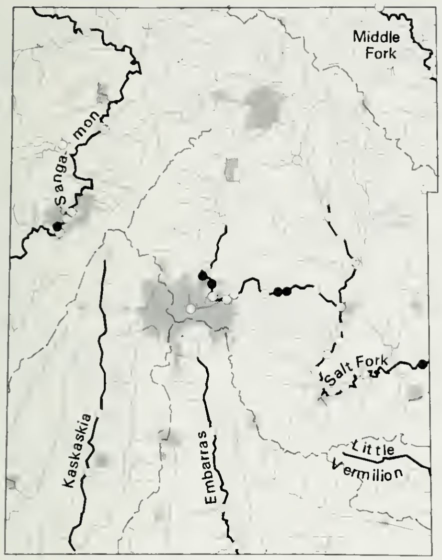
Larimore & Bayley (1987-88)

***Fundulus notatus*, blackstripe topminnow**

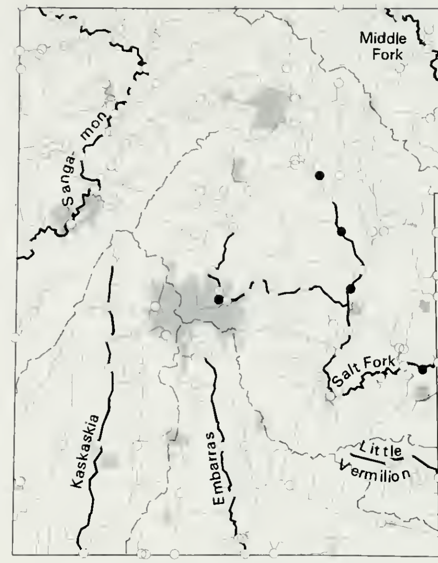
○ = species absent

● = species present

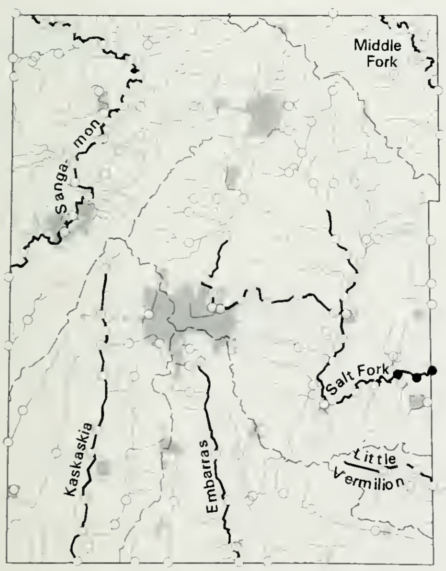
Figure 39



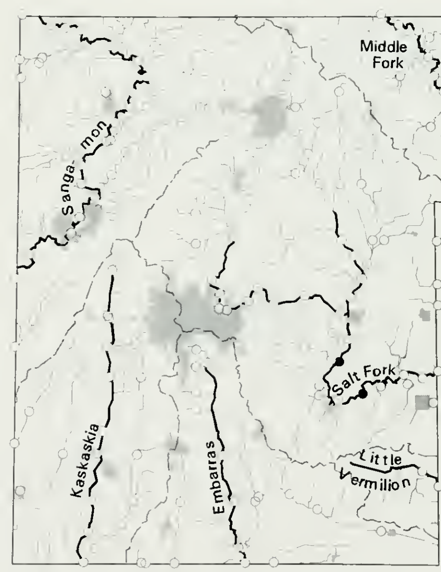
Forbes & Richardson (1889-91)



Thompson & Hunt (1928-29)



Larimore & Smith (1959-60)



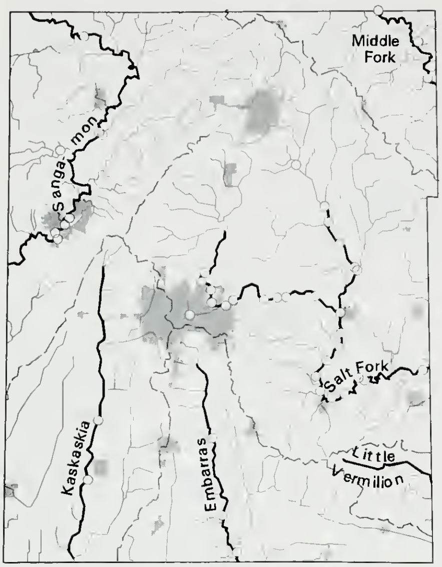
Larimore & Bayley (1987-88)

***Labidesthes sicculus*, brook silverside**

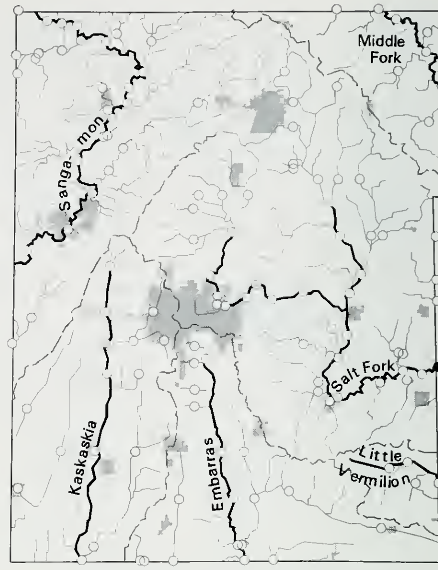
○ = species absent

● = species present

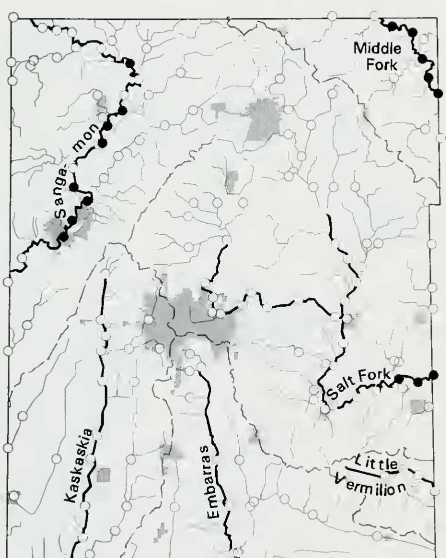
Figure 40



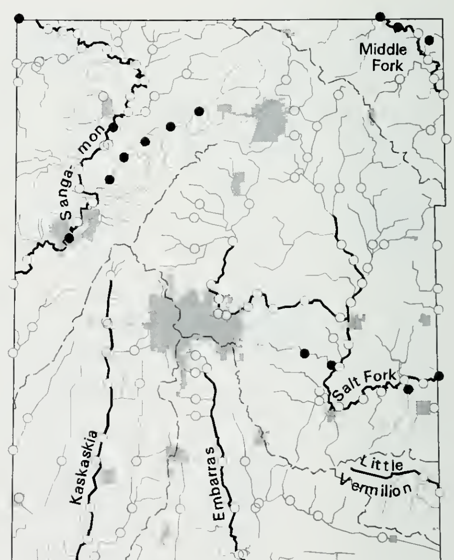
Forbes & Richardson (1889-91)



Thompson & Hunt (1928-29)



Larimore & Smith (1959-60)



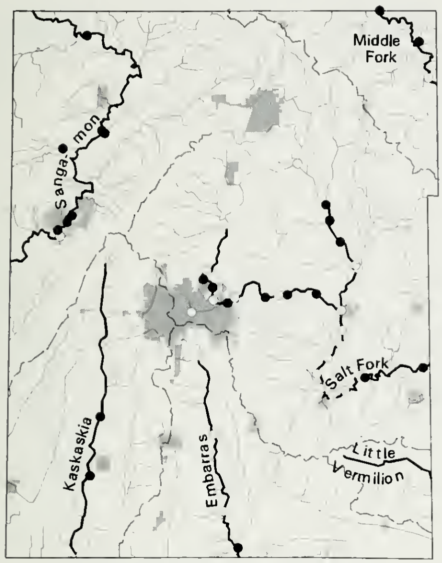
Larimore & Bayley (1987-88)

***Ambloplites rupestris*, rock bass**

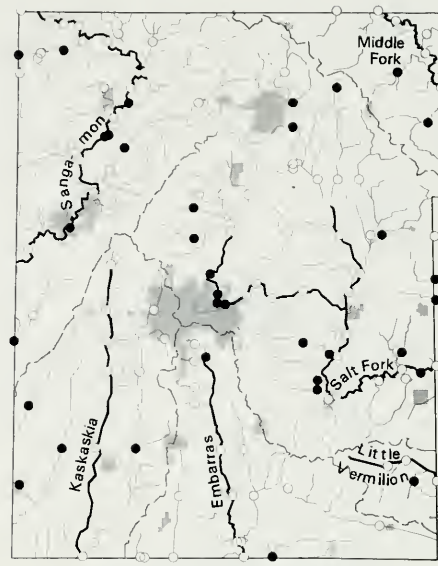
○ = species absent

● = species present

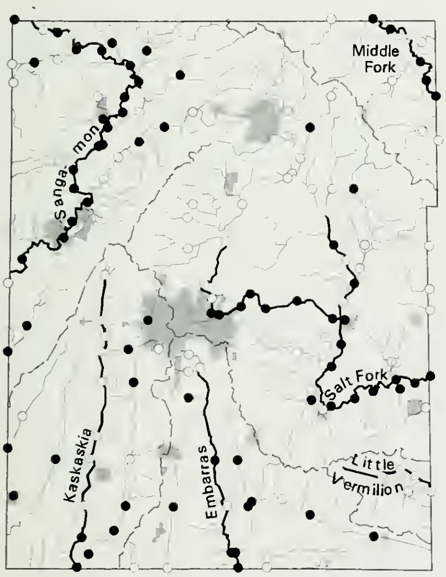
Figure 41



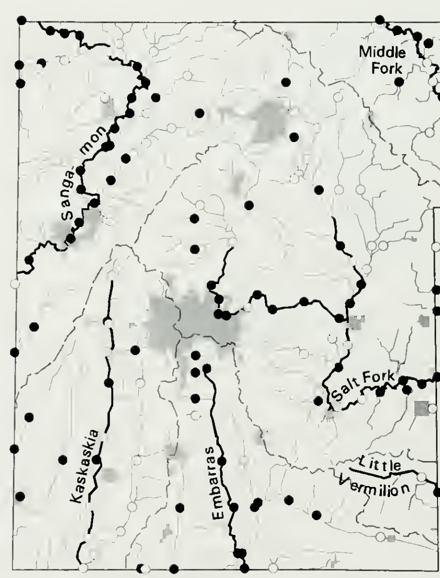
Forbes & Richardson (1889-91)



Thompson & Hunt (1928-29)



Larimore & Smith (1959-60)



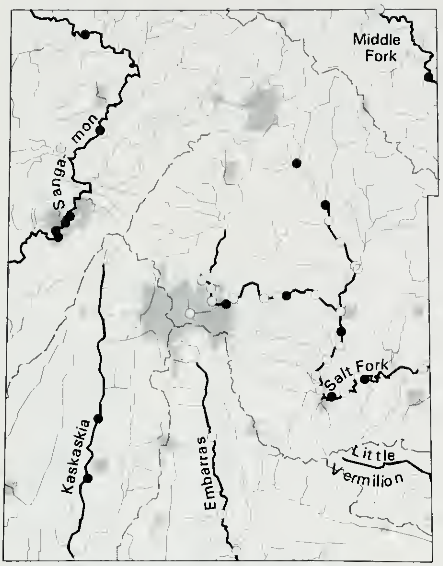
Larimore & Bayley (1987-88)

***Lepomis cyanellus*, green sunfish**

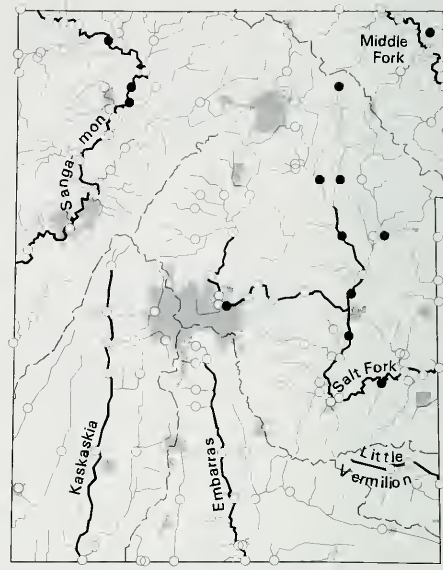
○ = species absent

● = species present

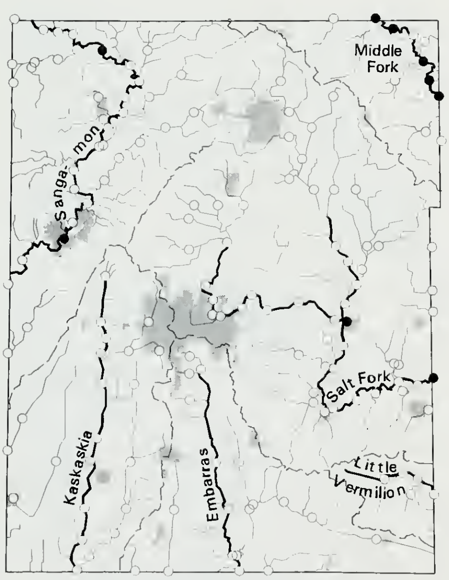
Figure 42



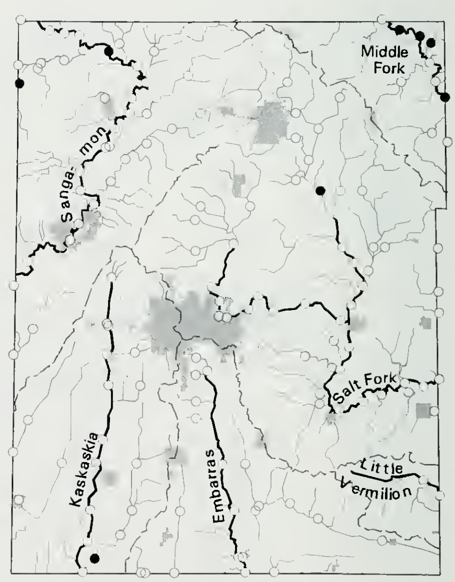
Forbes & Richardson (1889-91)



Thompson & Hunt (1928-29)



Larimore & Smith (1959-60)



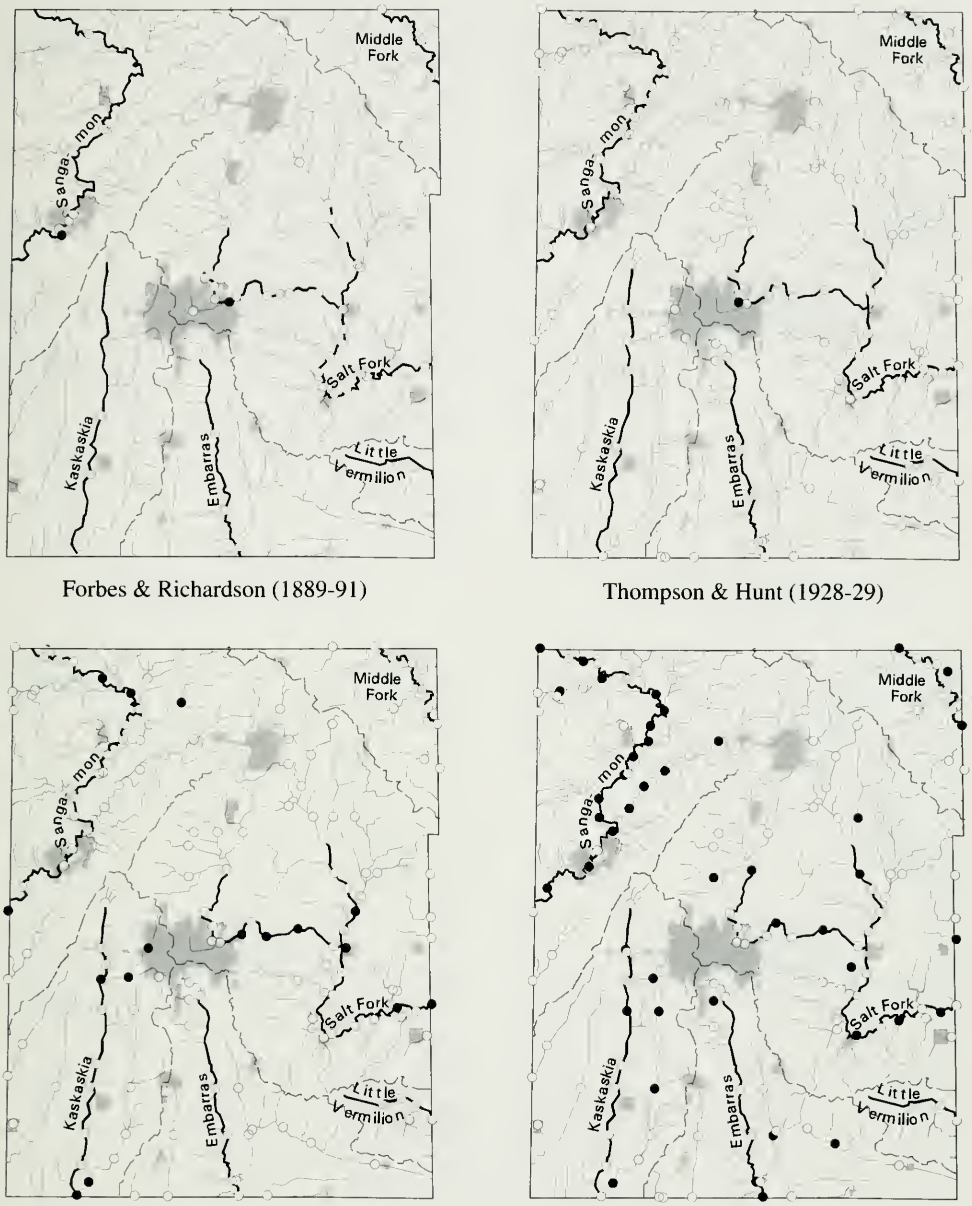
Larimore & Bayley (1987-88)

***Lepomis humilis*, orangespotted sunfish**

○ = species absent

● = species present

Figure 43



Forbes & Richardson (1889-91)

Thompson & Hunt (1928-29)

Larimore & Smith (1959-60)

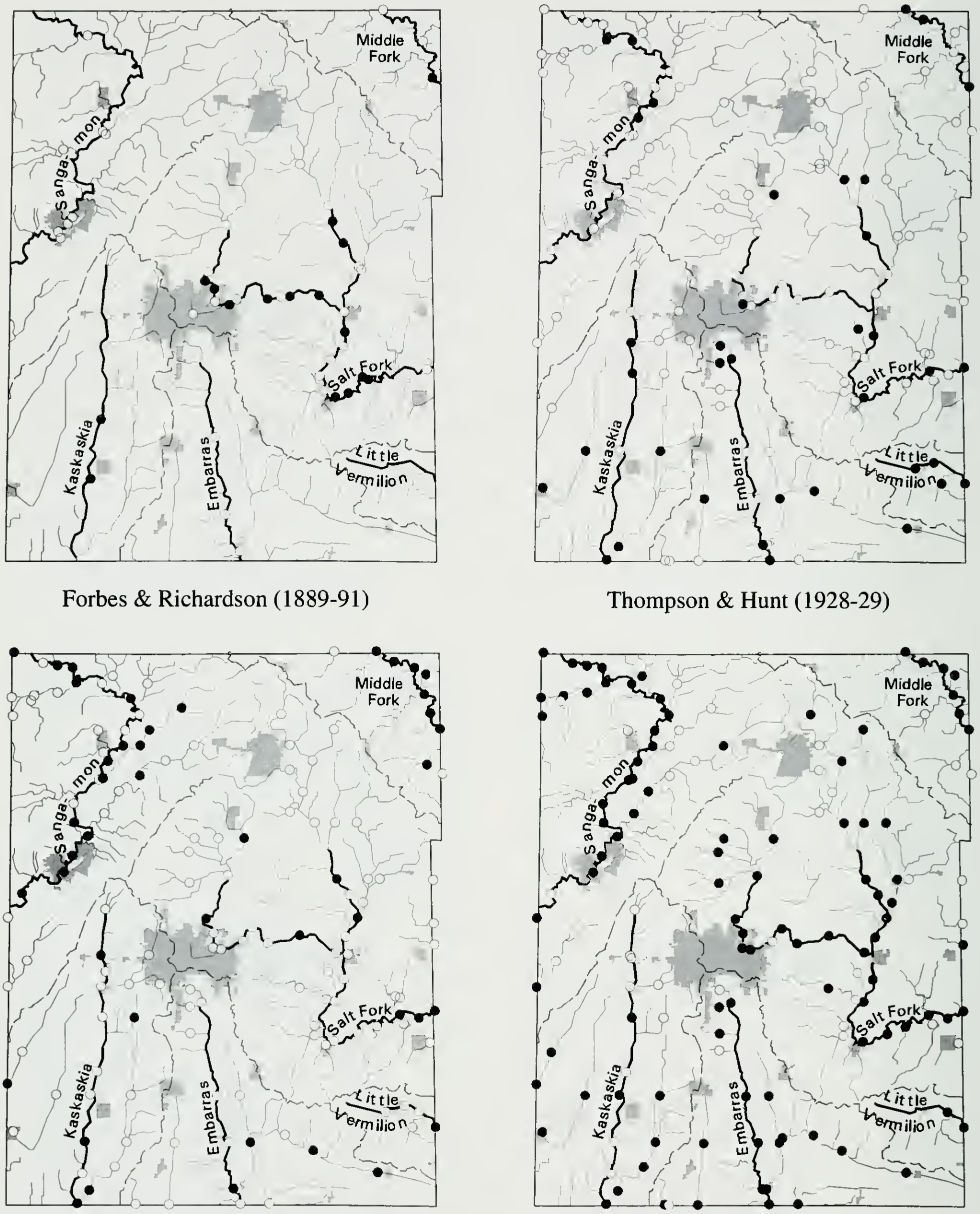
Larimore & Bayley (1987-88)

***Lepomis macrochirus*, bluegill**

○ = species absent

● = species present

Figure 44



Forbes & Richardson (1889-91)

Thompson & Hunt (1928-29)

Larimore & Smith (1959-60)

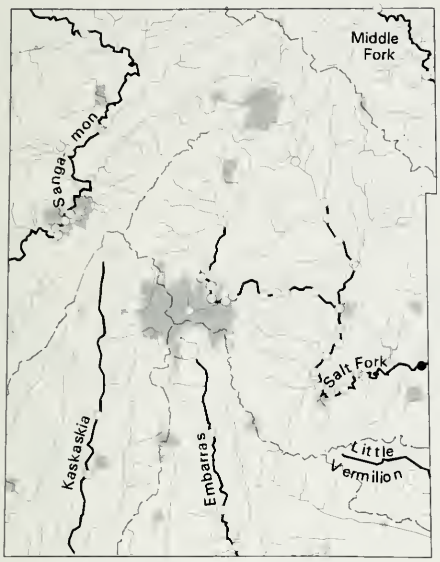
Larimore & Bayley (1987-88)

***Lepomis megalotis*, longear sunfish**

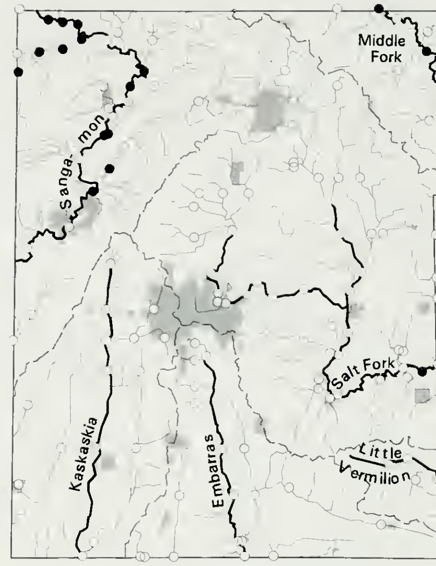
○ = species absent

● = species present

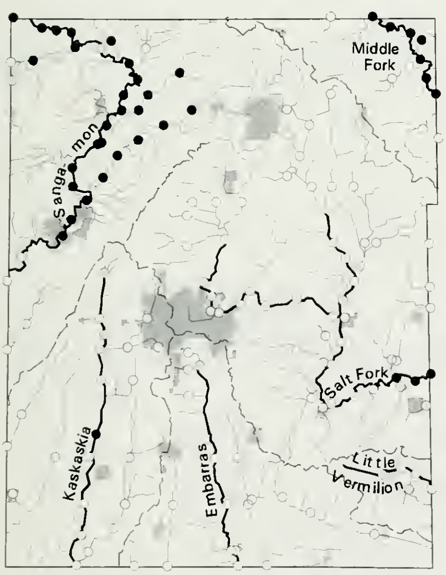
Figure 45



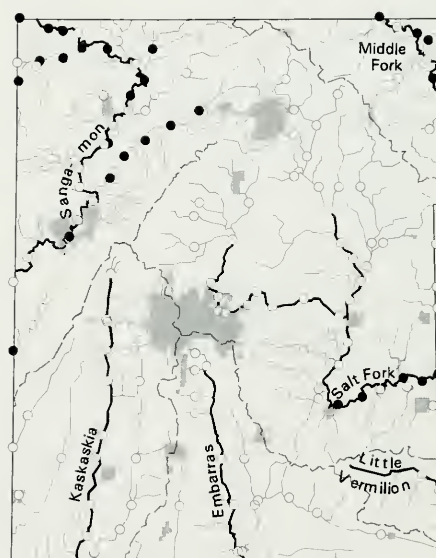
Forbes & Richardson (1889-91)



Thompson & Hunt (1928-29)



Larimore & Smith (1959-60)



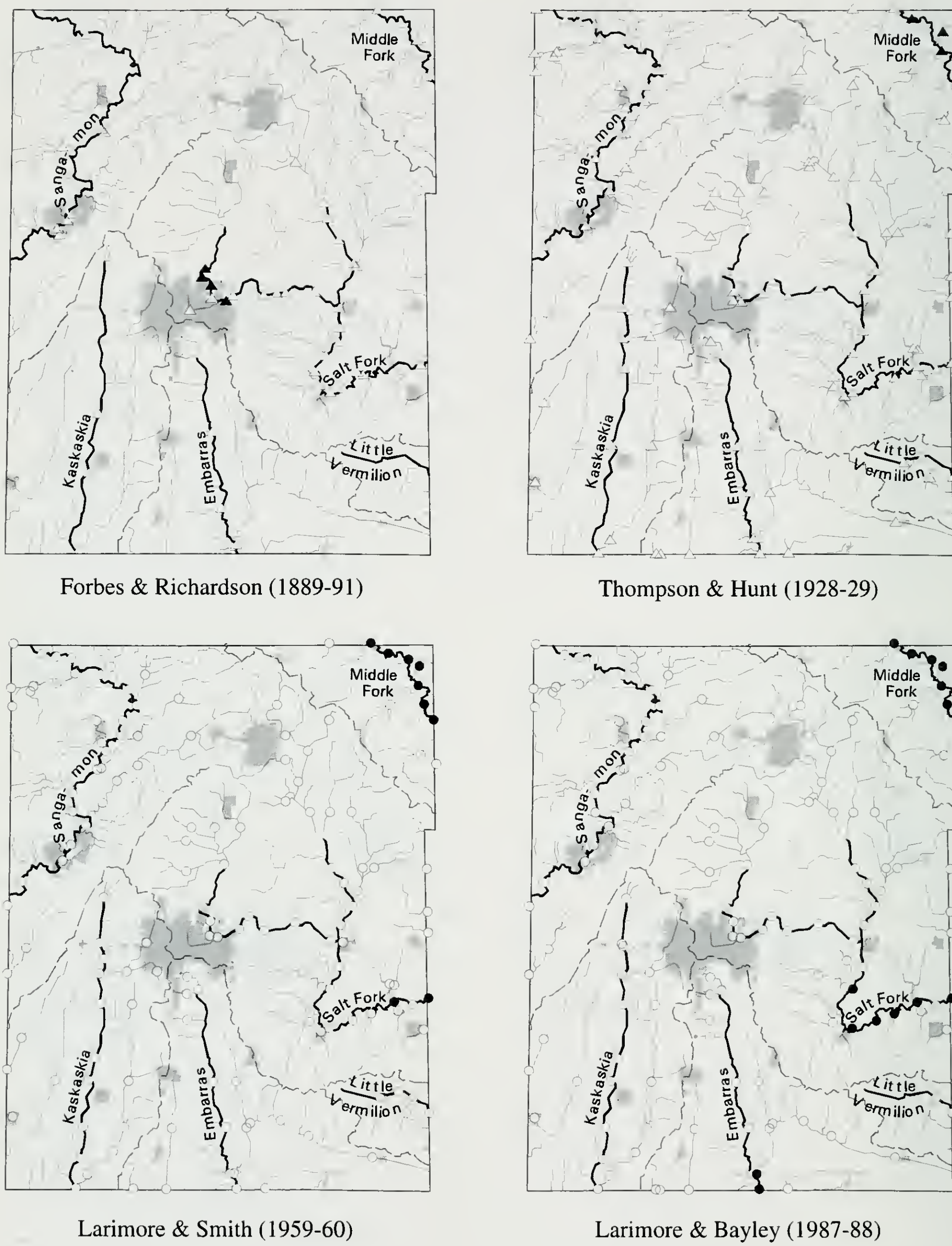
Larimore & Bayley (1987-88)

***Micropterus dolomieu*, smallmouth bass**

○ = species absent

● = species present

Figure 46



***Micropterus punctulatus*, spotted bass**
Composite with *M. salmoides*, largemouth bass

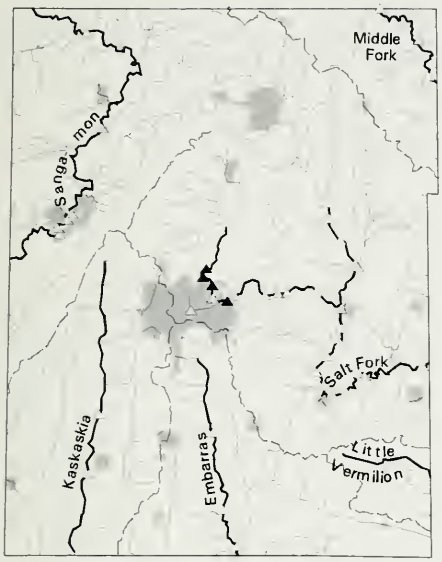
○ = species absent

● = species present

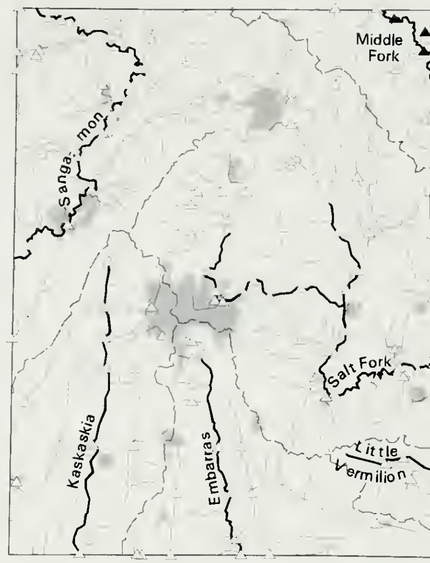
△ = composite absent

▲ = composite present

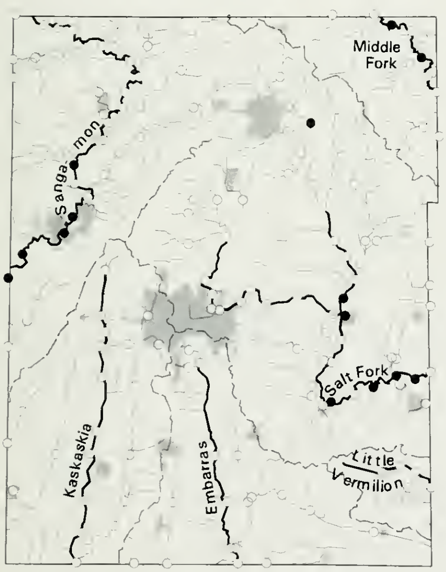
Figure 47



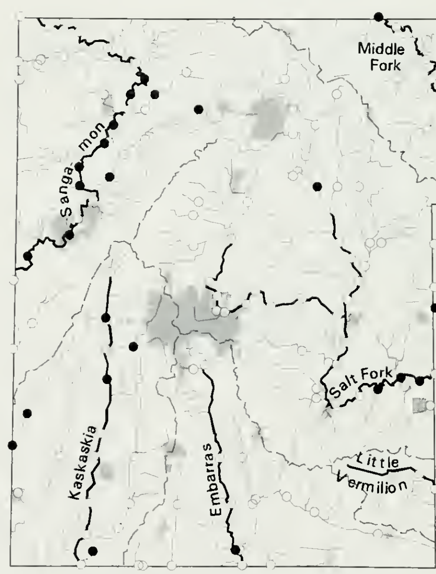
Forbes & Richardson (1889-91)



Thompson & Hunt (1928-29)



Larimore & Smith (1959-60)



Larimore & Bayley (1987-88)

***Micropterus salmoides*, largemouth bass**

Composite with *M. punctulatus*, spotted bass

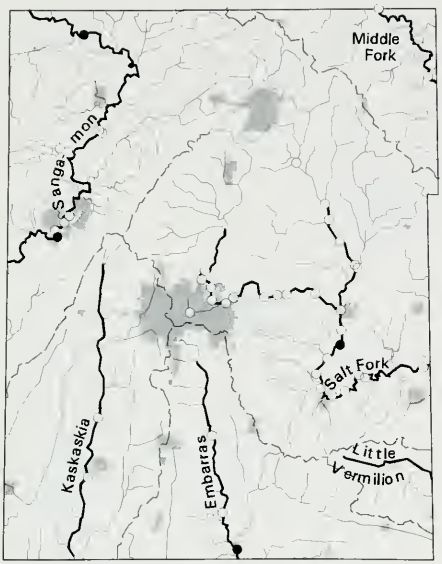
○ = species absent

● = species present

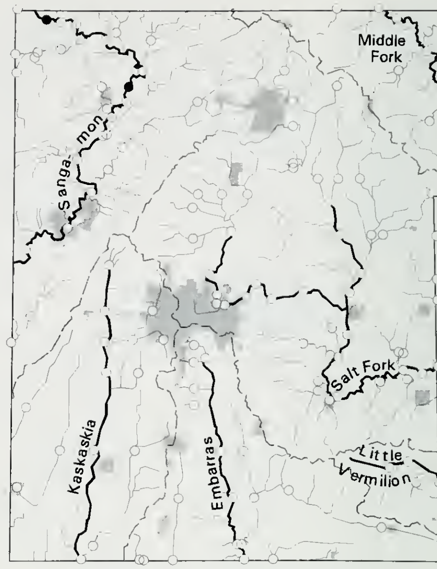
△ = composite absent

▲ = composite present

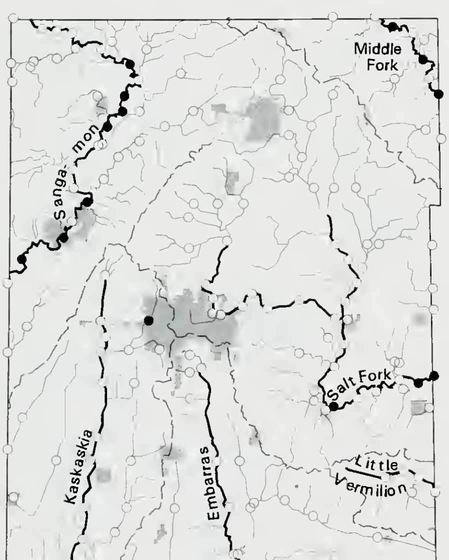
Figure 48



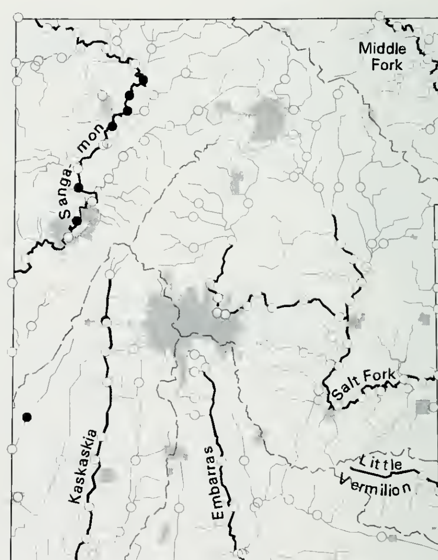
Forbes & Richardson (1889-91)



Thompson & Hunt (1928-29)



Larimore & Smith (1959-60)



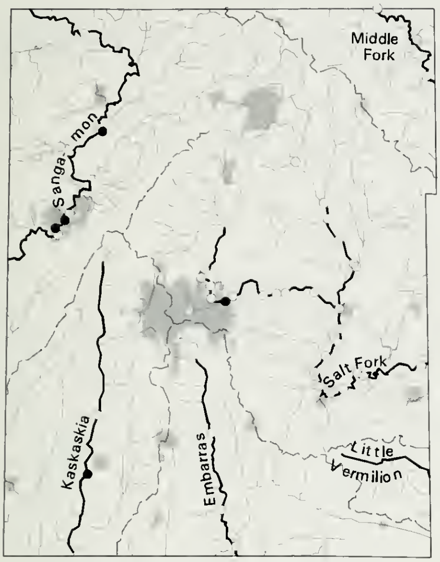
Larimore & Bayley (1987-88)

***Pomoxis annularis*, white crappie**

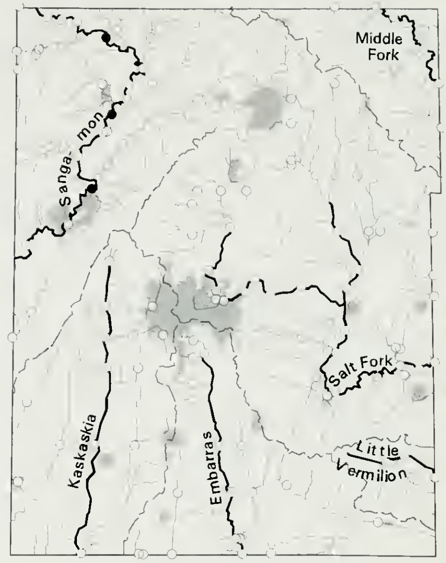
○ = species absent

● = species present

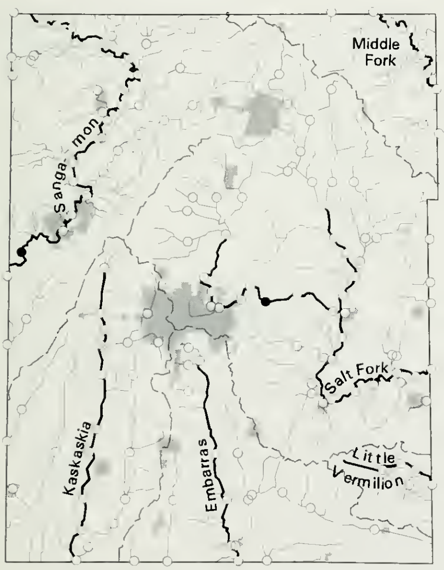
Figure 49



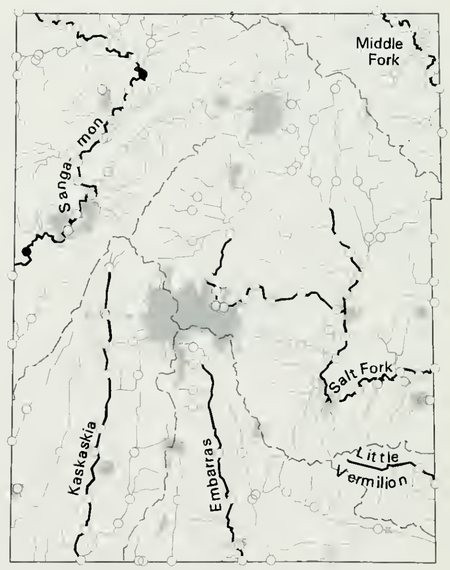
Forbes & Richardson (1889-91)



Thompson & Hunt (1928-29)



Larimore & Smith (1959-60)



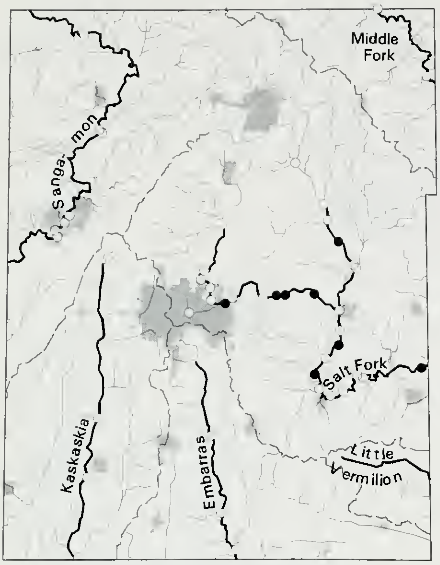
Larimore & Bayley (1987-88)

***Pomoxis nigromaculatus*, black crappie**

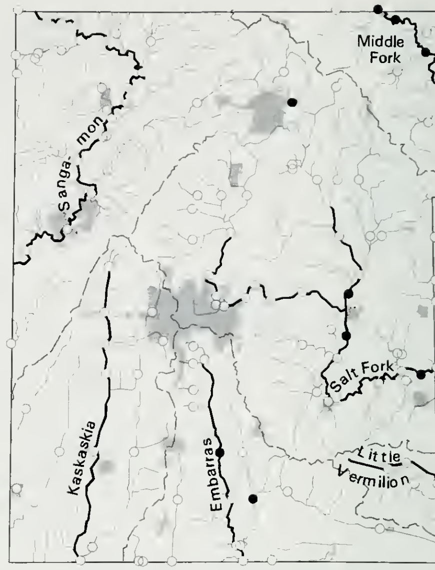
○ = species absent

● = species present

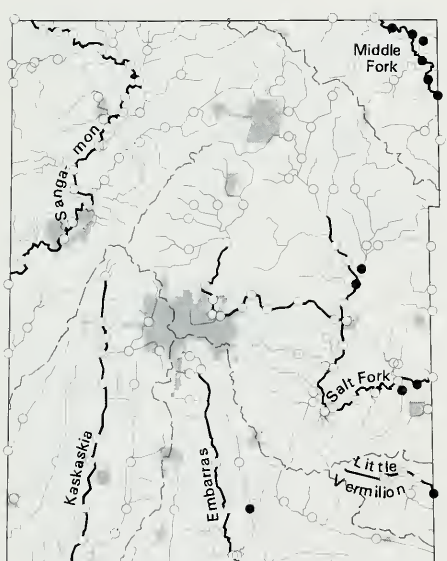
Figure 50



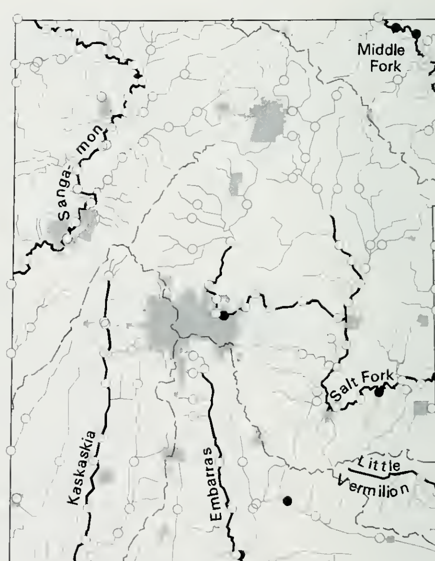
Forbes & Richardson (1889-91)



Thompson & Hunt (1928-29)



Larimore & Smith (1959-60)



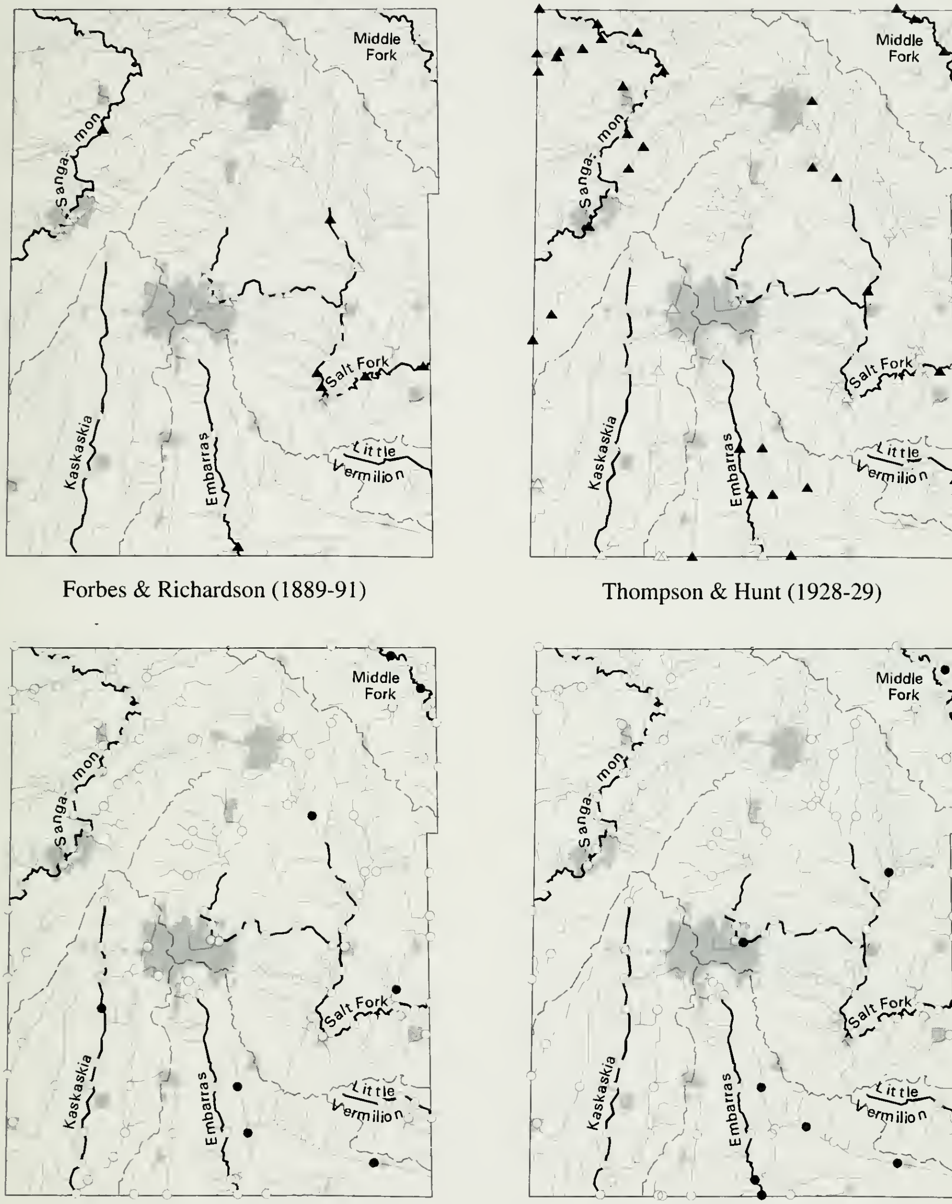
Larimore & Bayley (1987-88)

***Etheostoma blennioides*, greenside darter**

○ = species absent

● = species present

Figure 51



Forbes & Richardson (1889-91)

Thompson & Hunt (1928-29)

Larimore & Smith (1959-60)

Larimore & Bayley (1987-88)

***Etheostoma caeruleum*, rainbow darter**

Composite with *E. spectabile*, orangethroatt darter

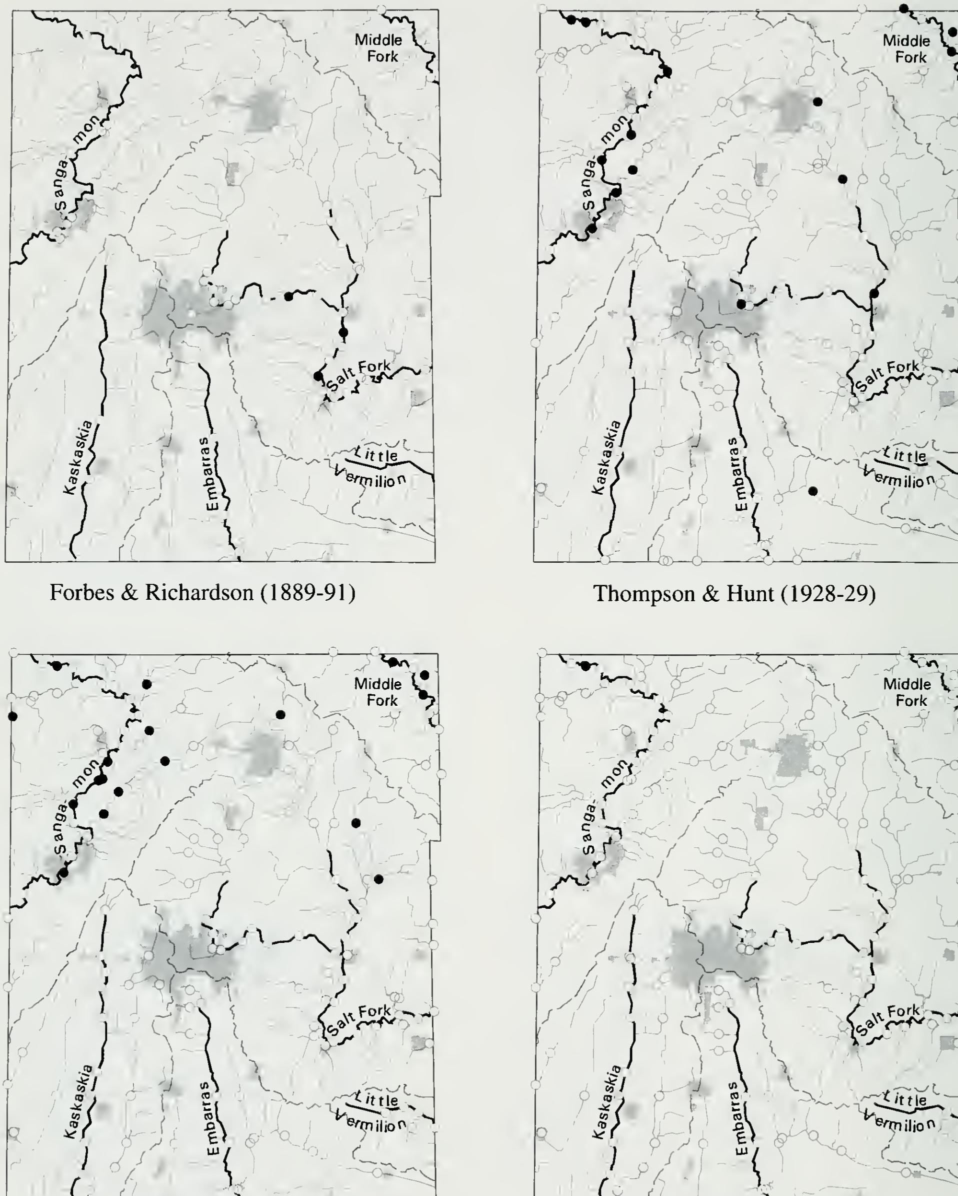
○ = species absent

● = species present

△ = composite absent

▲ = composite present

Figure 52



Forbes & Richardson (1889-91)

Thompson & Hunt (1928-29)

Larimore & Smith (1959-60)

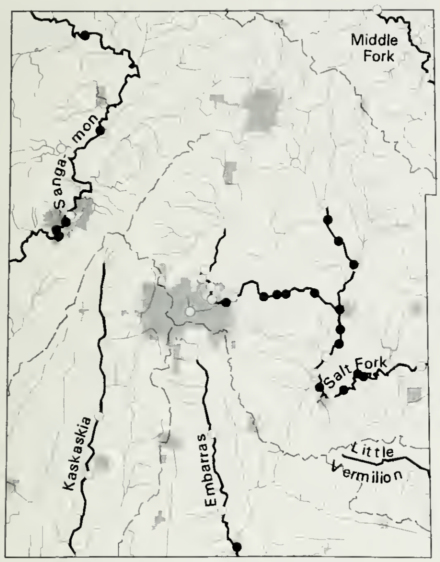
Larimore & Bayley (1987-88)

Etheostoma flabellare, fantail darter

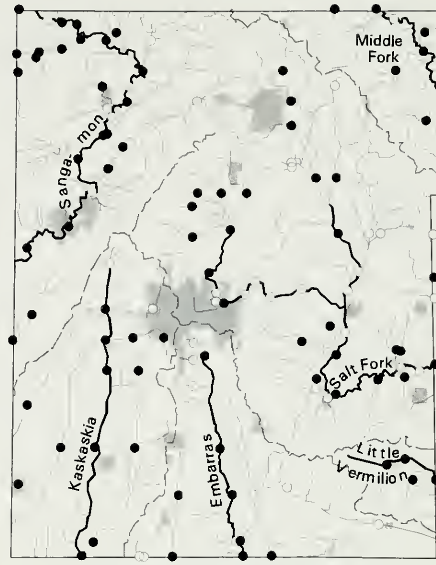
○ = species absent

● = species present

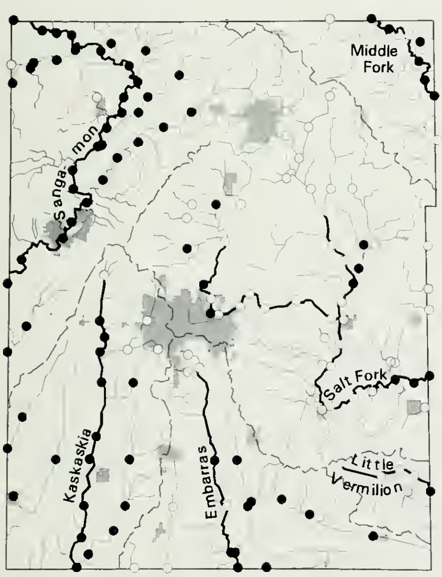
Figure 53



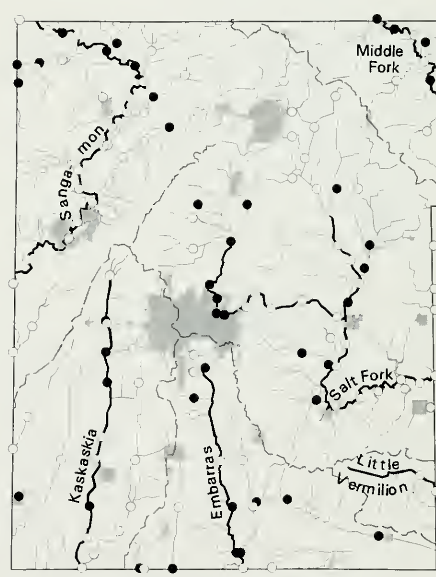
Forbes & Richardson (1889-91)



Thompson & Hunt (1928-29)



Larimore & Smith (1959-60)



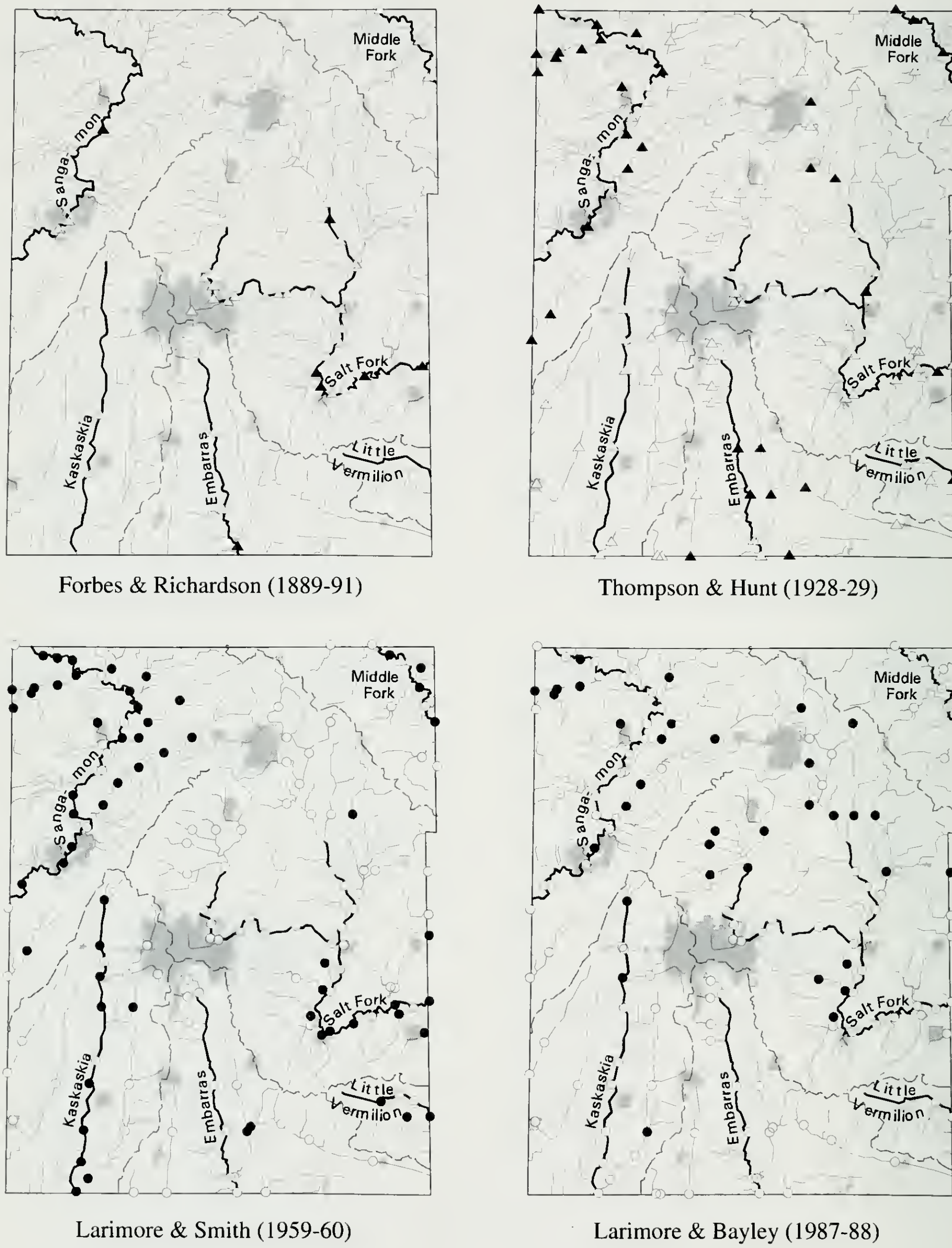
Larimore & Bayley (1987-88)

***Etheostoma nigrum*, johnny darter**

○ = species absent

● = species present

Figure 54



Forbes & Richardson (1889-91)

Thompson & Hunt (1928-29)

Larimore & Smith (1959-60)

Larimore & Bayley (1987-88)

***Etheostoma spectabile*, orangethroat darter**

Composite with *E. caeruleum*, rainbow darter

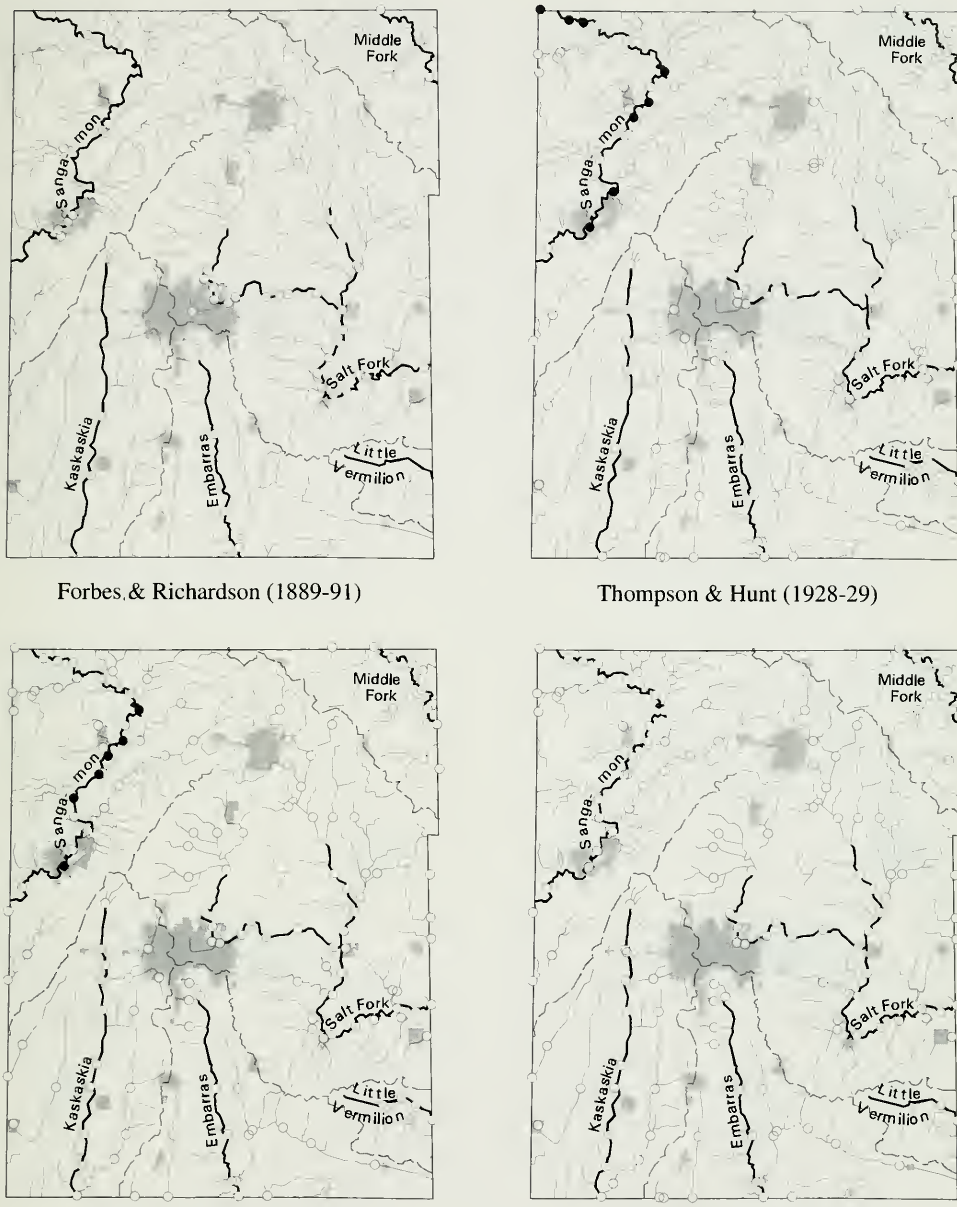
○ = species absent

● = species present

△ = composite absent

▲ = composite present

Figure 55



Forbes & Richardson (1889-91)

Thompson & Hunt (1928-29)

Larimore & Smith (1959-60)

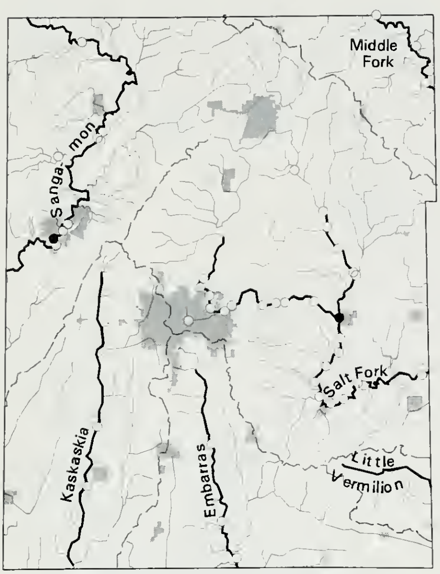
Larimore & Bayley (1987-88)

Etheostoma zonale, banded darter

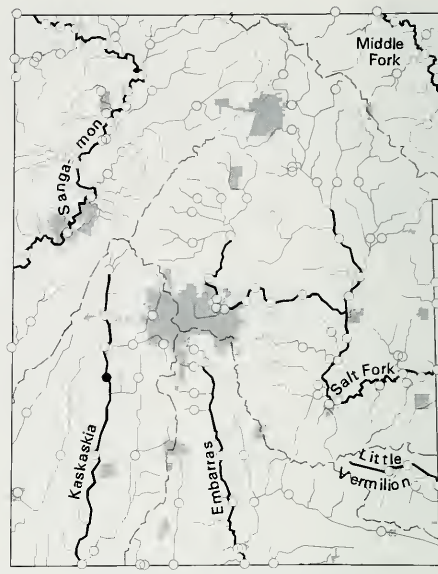
○ = species absent

● = species present

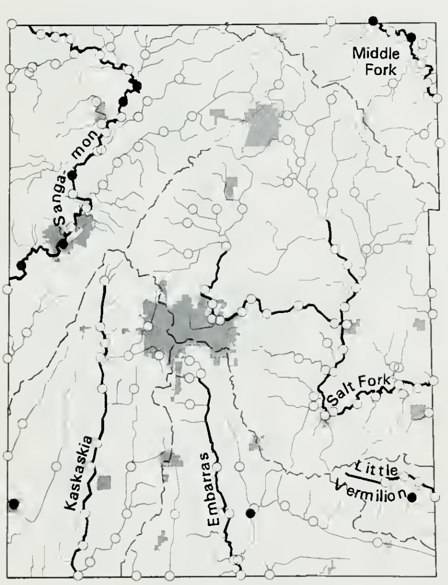
Figure 56



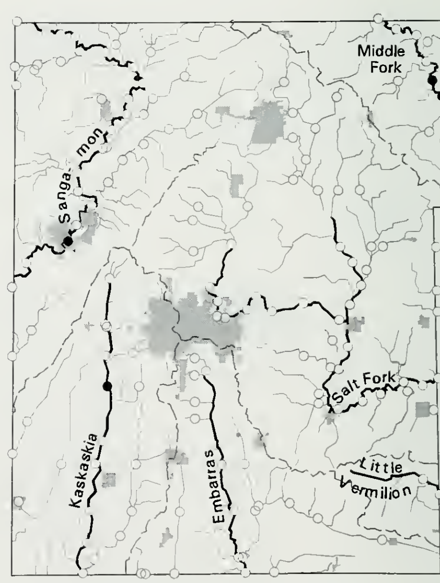
Forbes & Richardson (1889-91)



Thompson & Hunt (1928-29)



Larimore & Smith (1959-60)



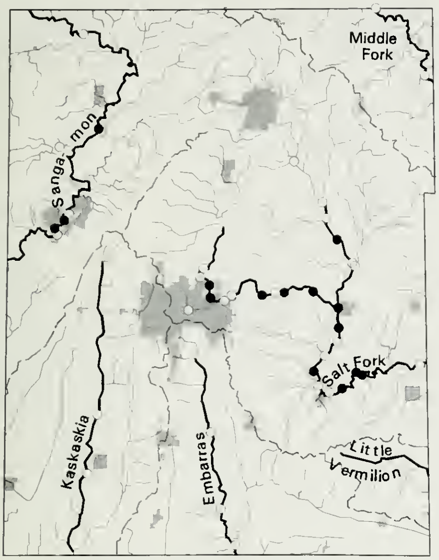
Larimore & Bayley (1987-88)

Percina caprodes, logperch

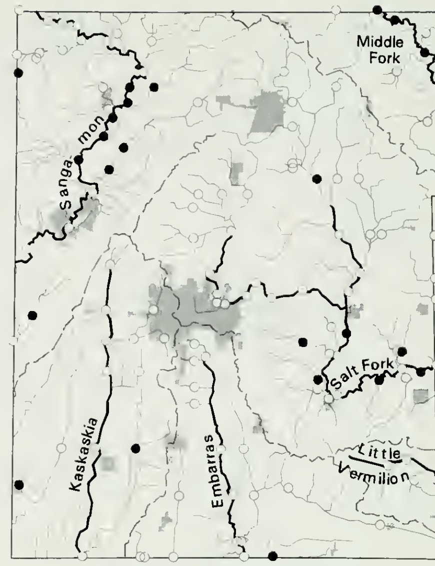
○ = species absent

● = species present

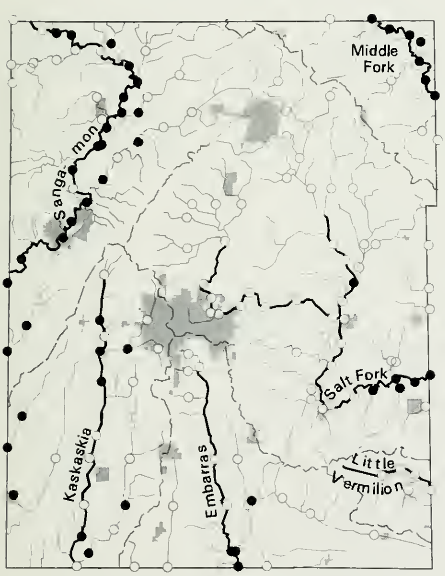
Figure 57



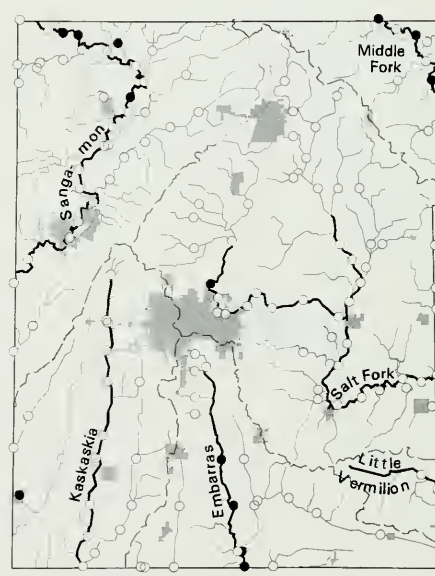
Forbes & Richardson (1889-91)



Thompson & Hunt (1928-29)



Larimore & Smith (1959-60)



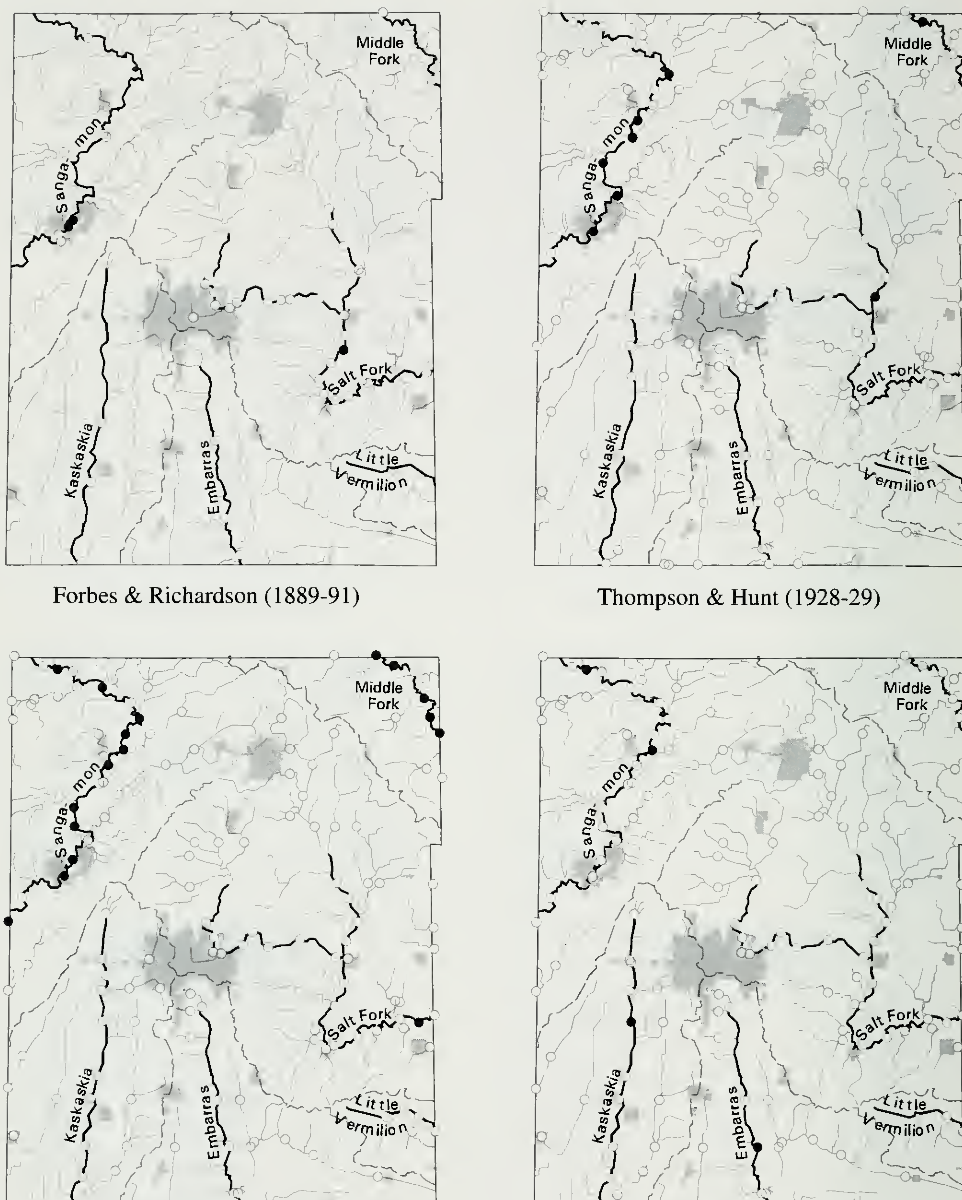
Larimore & Bayley (1987-88)

Percina maculata, blackside darter

○ = species absent

● = species present

Figure 58



Forbes & Richardson (1889-91)

Thompson & Hunt (1928-29)

Larimore & Smith (1959-60)

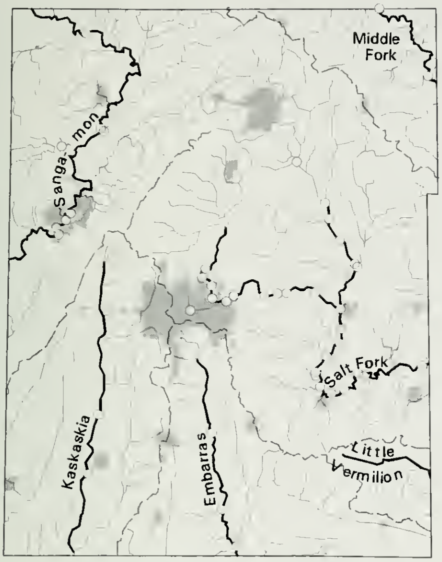
Larimore & Bayley (1987-88)

Percina phoxocephala, slenderhead darter

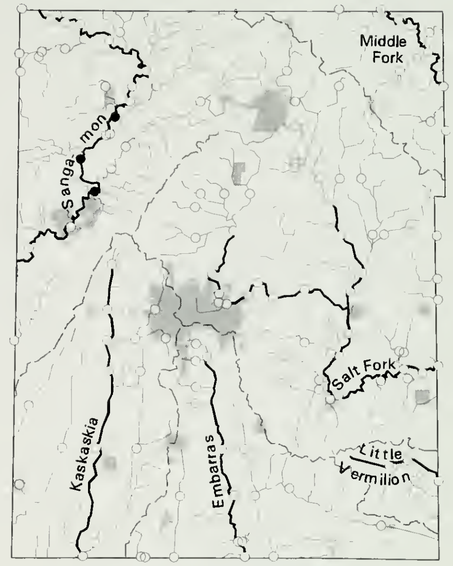
○ = species absent

● = species present

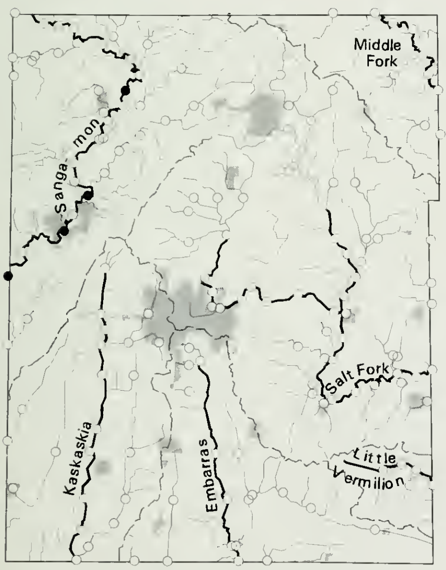
Figure 59



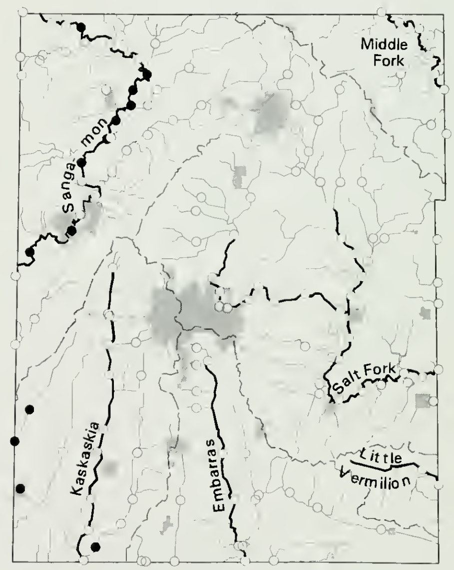
Forbes & Richardson (1889-91)



Thompson & Hunt (1928-29)



Larimore & Smith (1959-60)



Larimore & Bayley (1987-88)

Aplodinotus grunniens, freshwater drum

○ = species absent

● = species present

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