PRESENT STATUS AND DISTRIBUTION OF THE ARKANSAS RIVER SHINER, *NOTROPIS GIRARDI* (PISCES: CYPRINIDAE), AND POSSIBLE CAUSES FOR ITS DECLINE

By

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Bachelor of Science in Arts and Sciences

Oklahoma State University

Stillwater, Oklahoma

1988

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
December, 1991

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ACKNOWLEDGMENTS

I would like to extend my sincerest appreciation to Dr. Anthony A. Echelle for the opportunity to pursue my Master's degree and for his help and guidance in the completion of this study. Also, I would like to thank Alice Echelle, Mike Larson, Robert D. Larson Sr., Beth Nord, Bill Stark, Geff Luttrell, Chris Taylor and Jimmie Pigg for their assistance in the field and Susan Merrifield for her help in the laboratory. The help of Dr. Sterling L. Burks and Bill Stark in the use of computers and invaluable discussion is greatly appreciated. I am also grateful for constructive discussions with Dr. Alexander V. Zale, Dr. Larry Talent, and Jimmie Pigg.

Special thanks are due to the U. S. Fish and Wildlife Service, and the Oklahoma Cooperative Fish and Wildlife Research Unit for the financial support I received and for the use of field equipment during the course of this work.

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CHAPTER I

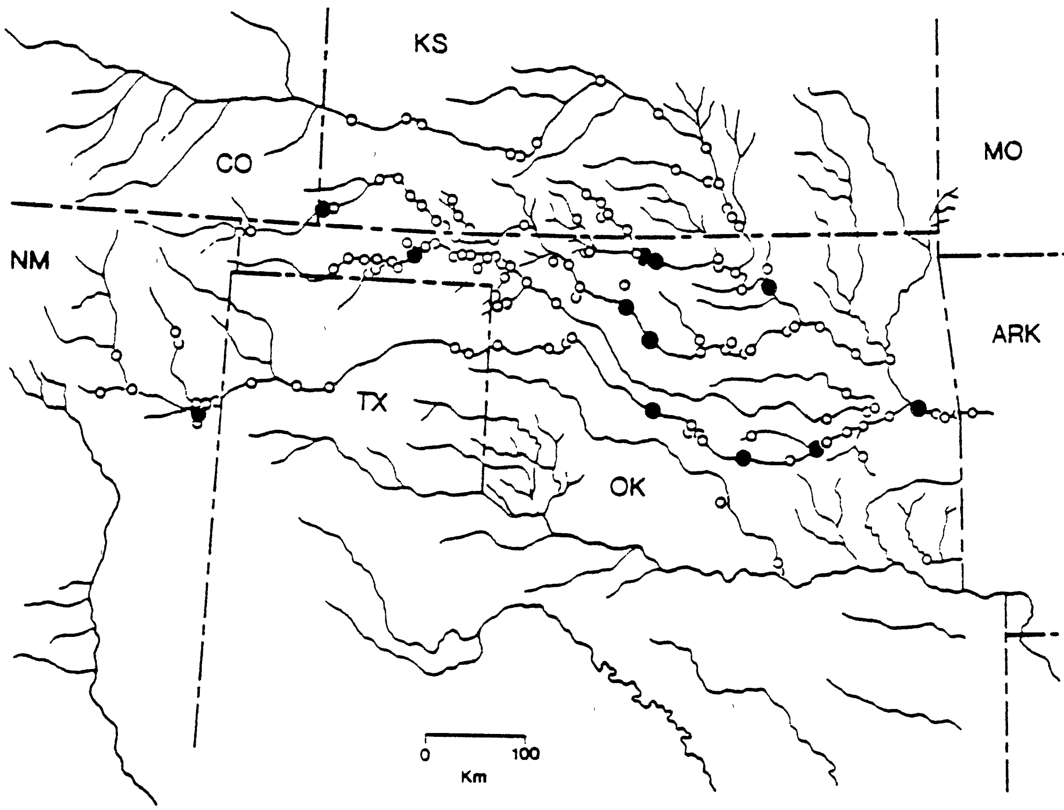
INTRODUCTION

The Arkansas River shiner, *Notropis girardi*, was first discovered in 1926 in the Cimarron River, northwest of Kenton in Cimarron County, Oklahoma (Hubbs and Ortenburger 1929). It is a small, pallid shiner with mature adults ranging in size from 25-45 mm SL (Gilbert 1980). The species is a member of the small subgenus *Alburnops*, which also includes *N. bairdi*, *N. potteri*, and *N. blennius* among Oklahoma fishes (Mayden 1989).

The shiner was at one time widespread and abundant in the Arkansas River and its major tributaries. These tributaries include the Cimarron, North Canadian and South Canadian rivers which flow through the regions of southwestern Kansas, southeastern Colorado, northeastern New Mexico, the panhandle of Texas, the northern half of Oklahoma, and western Arkansas (Fig. 1). During the past 20-30 years, however, abundance and distribution of the Arkansas River shiner have declined markedly.

Felley and Cothran (1981) were the first to document the decline of the Arkansas River shiner in Oklahoma. They reported that although the species was found at 6 of 11 sites sampled in 1979, their numbers (4 specimens in the

Figure 1. Historical distribution of the Arkansas River shiner. Data for the map were taken from museum records in Appendix A. Open circles = pre-1985 occurrences; closed circles = occurrences from 1985-1988.


KS
MO
CO
NM
ARK
TX
OK
0
100
Km

largest collection) reflected a major decline. Cross et al. (1985) found specimens at only two sites in Kansas, both in the Cimarron River, during a 1983 survey and reported that the species was on the verge of being extirpated from the state. Since then, there has been only one recorded collection of the species in Kansas; a single specimen was collected from the Cimarron River, Morton County, in 1987 (Eberle et al. 1989). The species has not been collected from Arkansas since 1939 and is probably extirpated there (Robison and Buchanan 1984). Bestgen et al. (1989) reported that the Arkansas River shiner was introduced in the Pecos River, New Mexico in 1978 and had become widespread and abundant in the drainage by 1986-87.

The most recent collection of the Arkansas River shiner in Oklahoma, except for collections from the South Canadian River, was from a site on the North Canadian River in Beaver County in 1987 (Pigg in press) suggesting that, although still abundant in the South Canadian River, the species was extirpated from the Cimarron, Arkansas, and North Canadian rivers.

The Arkansas River shiner inhabits the main channels of sandy streams and rivers in the Arkansas River drainage (Gilbert 1980, Miller and Robison 1973, Cross and Collins 1975). These rivers are generally broad and unshaded, with highly variable flows subject to high summer temperatures, high rates of evaporation and high concentrations of dissolved solids (Cross 1985).

Moore (1944) found eggs of the Arkansas River shiner in the Cimarron River during a period of high flow in July and concluded that spawning probably occurs after mid-summer rain events. The eggs are pelagic and are carried by the current, presumably many miles downstream. Hatching occurs within 48 hours of spawning.

The cause of the decline of the Arkansas River shiner is unknown. Cross et al. (1983) suggested that alterations in flow regimes may be the principal reason for its decline. Impoundment and diversion of flow for irrigation may have decreased the frequency of mid-summer peak flows that this species appears to be dependent on for reproductive success. Oklahoma contains the largest remaining populations of the Arkansas River shiner within its historic range. This population seems to be restricted to a single river system, the South Canadian, and therefore is at risk should alterations in this river system occur.

The objectives of this study were to 1) determine the present distribution and status of the Arkansas River shiner; 2) analyze flow and water quality characteristics in the major tributaries of the Arkansas River basin to determine whether there have been significant changes in flow and/or water chemistry that may explain why the Arkansas River shiner has declined; 3) describe seasonal changes in reproductive condition; and 4) make recommendations for management planning and status assessment.

CHAPTER II

MATERIALS AND METHODS

We documented the current status and distribution of this species by intensively sampling areas of known historical occurrence. Sampling emphasized sites from which the species was previously recorded. Sample sites were selected by examining past records of occurrence from the following museum collections (Appendix A): University of Oklahoma, Stovall Museum of Zoology, (UOMZ); University of New Mexico, Museum of Southwestern Biology (MSB); University of Texas, Texas Memorial Museum (TNHC); Eastern New Mexico University, Portales (ENMU); University of Kansas, Museum of Natural History (KU); University of Michigan, Museum of Zoology (UMMZ); and Oklahoma State University Collection of Vertebrates (OSUS). The majority of the sampling sites were on the mainstems of the larger rivers in the Arkansas River basin in Oklahoma. Surveys were also conducted on the South Canadian River in the panhandle of Texas and northeastern New Mexico and the Cimarron River in southwestern Kansas. Although the Cimarron River flows through a small section of southeastern Colorado, there are no known records of this species being taken from this region and consequently this section of the river was not sampled.

At each sample site, shallow-water (<1 m) habitats were seined with a 3.6 m x 1.8 m minnow seine of 3.2 mm mesh. Water and air temperatures were recorded along with several qualitative habitat features, such as, substrate size, maximum depth, stream width, etc. All collections were preserved and transported to the laboratory in 10% formalin where they were sorted by species. Most specimens were catalogued in the OSU Collection of Vertebrates and stored in 45% isopropyl alcohol. Species and abundances at each sample site were recorded and tabulated. These catalogued specimens will allow future workers to verify the presence or absence of the Arkansas River shiner in our collections. Furthermore, they represent a documented record for the occurrence of other prairie fishes, some of which (e.g., *Notropis stramineus*, *Extrarius aestivalis*, and *Platygobio gracilis*) appear to be declining (personal observations; J. Pigg, personal communication).

Our collections from 1989-1991 were supplemented with an additional 120 collections made throughout the Arkansas River drainage in 1988-1990 by J. Pigg (Oklahoma Department of Health). These collections were sorted and catalogued into the Oklahoma State University Collection of Vertebrates (OSUS). Due to time and space constraints, only those species closely resembling the Arkansas River shiner or rare and unique species were saved and catalogued. These collections were made in a standard manner (J. Pigg, personnel communication), allowing assessment of relative abundances in different years. Most of the annual samples for each site comprise more than one collection during the year (see Appendix B). The values shown in Table 1 represent the mean number per collection per year.

J. Pigg has sampled at a number of sites in the Arkansas River basin on an annual basis. We used his collections from selected sites on each of the major tributaries to determine the pattern of decline of the Arkansas River shiner between 1976 to 1988. These included a total of 13 sites as follows (Appendix B): two sites on the Salt Fork of the Arkansas River, three sites on the Arkansas River, four sites on the Cimarron River, two sites in the North Canadian River, and two sites in the South Canadian River. Except for the two sites on the South Canadian River, all collections from each site were sorted by species and catalogued in the Oklahoma State University Collection of Vertebrates (OSUS).

Two study efforts were conducted which, while not directly elucidating the present distribution and abundance of the species, are (as discussed later) potentially important in determining the status of existing populations in the South Canadian River. From June 1989 to October 1990, collections were made to determine the period of peak reproductive activity as estimated from gonadosomatic indices and measurements of egg diameters. These collections were made on a biweekly (during the presumed spawning season) or a monthly basis at two sites in the

South Canadian River where the species remains common (at bridge crossings for Interstate Highways 35 and 44 on the McClain/Cleveland county line near Oklahoma City).

We also performed a study of changes during the past 30 or more years in flow (discharge) characteristics and water quality (conductivity and turbidity) in the major rivers within the range of the species. Stream flow records were obtained from Dr. S.L. Burks (Zoology Department, Oklahoma State University) from a computerized data bank (Hydrodata @) that contained all records from USGS stations on rivers in Oklahoma, Texas, and Kansas. We analyzed mean daily discharge records to determine whether changes in historic flow regimes occurred and whether these changes coincided with the decline of the Arkansas River shiner in the 1970's and 1980's. Discharge data were examined from each of three widely separated sites on each of the major rivers in the Arkansas River basin (Arkansas, Cimarron, North Canadian, and South Canadian rivers). The mean daily discharge records at each site were grouped into three historical periods of time: origin of records through 1949; 1950-69; and 1970 to the last year for which complete daily records of water years (ending September 30) were available. To compare flow regimes of the three historical periods, five percentiles of mean daily discharge (10th, 25th, 50th, 75th, and 90th) were computed for each period. Semilogarithmic plots of these values provided a "flow duration curve" for each historical period. For example, the 10th percentile is the discharge exceeded by 90% of the records. The shape and magnitude of such curves are sensitive indicators of the frequency distribution of the total collection of records for a given historical period (Cross et al. 1985).

To allow seasonal comparisons among historical periods, the 10th and 90th percentiles of mean daily discharge records were computed for each of the 12 months across each historical period. The resulting values reflect seasonality at the two extremes of the frequency distribution of discharge records (low flows = 10th percentile; high flows = 90th percentile).

Tests of significance in the monthly differences in high flows between historical periods were performed as follows. First, for each month, we computed the mean of the three mean daily discharge values corresponding to the 90th percentile for the three historical periods. Then, pairwise Mann-Whitney tests of significance among historical periods were performed on all values for that month which were greater than the computed average. In similar tests for monthly differences in low flows, we used the average value for the 10th percentiles of the three periods and performed Mann-Whitney tests on all values less than the computed average. The Bonferonni method was used to assess significance of individual tests within each pairwise comparison of historical periods. We also examined monthly maximum discharges from May through August. These months encompass the reproductive season of the shiner and peak summer flows are thought to be important for successful reproduction in the Arkansas River shiner (Moore 1944).

Conductivity data were analyzed on a monthly basis in the same manner as the discharge data; however, fewer sites were available for analysis and many of these sites had only partial records. The sites selected included: Arkansas River at Arkansas City, Cowley County, KS, and Ralston, Pawnee County, OK; Cimarron River at Perkins, Payne County, OK; North Canadian River at Wetumka, Hughes County, OK; and the South Canadian River at Calvin, Hughes County, OK. No daily records for turbidity exist. Turbidity measurements were taken irregularly and were not extensive.

The commercial minnow harvest from the Arkansas River basin was examined for possible impact on Arkansas River shiner. Harvest records were obtained from a 1990 annual report from the Oklahoma Department of Wildlife Conservation. Although these records do not identify what minnow species were actually taken, they do allow a rough assessment of possible impact.

CHAPTER III

RESULTS

Past Distribution and Introductions

The historical distribution of the Arkansas River shiner is illustrated in Figure 1. The shiner is endemic to the Arkansas River basin. There are records of four collections of the species from the Red River drainage; Cross (1970) reported a single specimen from Wildhorse Creek, in the Washita drainage system, and the Oklahoma Museum of Natural History has records of two collections from the Lake Texoma area and one collection from McCurtain County. It is unknown how these individuals appeared in the Red River drainage system, but migration from the Arkansas River drainage appears unlikely. The most recent collections of the species outside of its native range are from the Pecos River where it has dispersed over about 300 km of river and is abundant in some areas (Bestgen et al. 1989). Figure 1 also shows the sites where the species was collected during the five years prior to our 1989-91 survey. All of the Oklahoma collections were made by J. Pigg of the Oklahoma Department of Health. Collections from the survey by Bestgen et al. (1989) in the Pecos River were not included in Figure 1 as these represent introduced populations outside the native range of the species.

Trends in Abundance Between 1976 and 1990

Table 1 shows the trends in relative abundance of Arkansas River shiner at 13 selected sites that were sampled repeatedly over 9-15 years by J. Pigg. Throughout the period of concern (1976-1990), the Arkansas River shiner was relatively uncommon in samples from the mainstem of the Arkansas River (sites 9-11) and one site on the North Canadian River (site 2). Thus, these sites provide little information regarding trends of occurrence. Trends are, however, evident in the collections from sites on the Cimarron River, the Salt Fork of the Arkansas River, and one site on the North Canadian River. From 1976 into 1983, the shiner generally was present in collections from those sites. However, between 1983 and 1985, the numbers of specimens showed a marked decline. After 1985, samples usually produced no specimens of the species. When collected at a site, the species typically was represented by only a single specimen. The only exceptions were collections of 3 and 4 specimens, respectively, in 1987 and 1990 from the site on the North Canadian River.

The most conspicuous event associated with the decline of the Arkansas River shiner after 1983 was a severe summertime drought that occurred in 1984. Figure 2 shows the monthly maximum flows at two sites in the Cimarron River during the breeding season of the Arkansas River shiner

TABLE 1

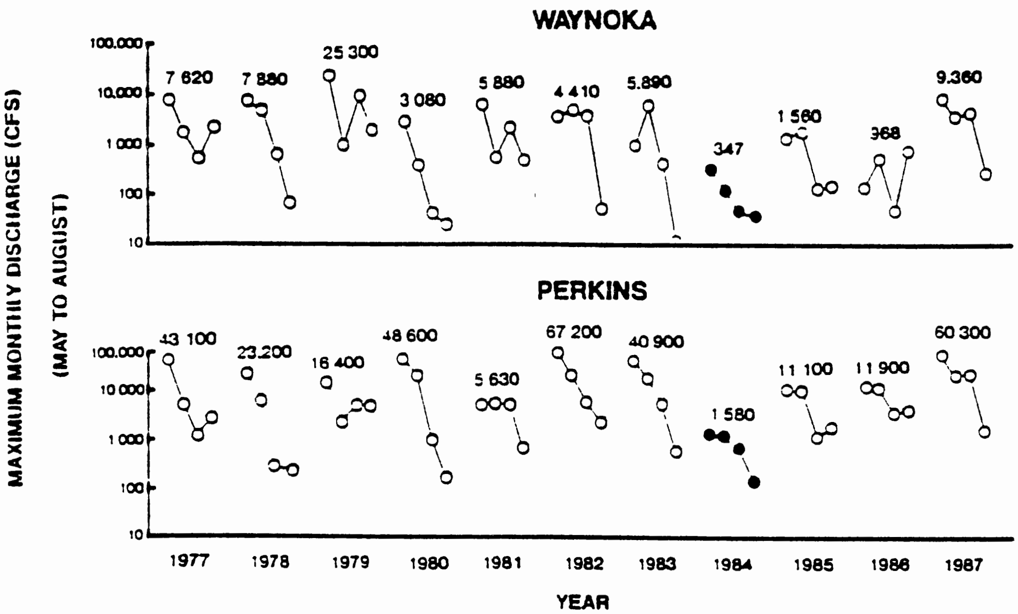
RELATIVE ABUNDANCE OF ARKANSAS RIVER SHINER COLLECTED AT EACH OF 13 STATIONS *,**

Year	Drainage/Sites												
	South Canadian River		North Canadian River		Cimarron River				Salt Fk. of the Arkansas		Arkansas River		
	1	2	3	4	5	6	7	8	9	10	11	12	13
1976	-	-	-	-	-	-	-	25.0	0.0	-	-	-	-
1977	428.5	704.0	-	-	-	-	-	166.5	15.0	-	3.0	0.5	-
1978	1904.5	0.0	-	0.0	-	-	-	20.5	27.3	-	6.5	0.0	0.0
1979	1641.0	302.6	-	0.0	-	42.5	522.7	56.0	3.5	2.7	0.0	0.0	0.0
1980	623.0	619.0	-	6.5	-	6.5	7.0	9.3	9.3	1.3	0.7	0.0	0.0
1981	191.0	173.0	-	2.7	0.0	27.0	4.5	68.0	4.7	35.0	0.0	0.0	0.0
1982	285.3	406.0	25.0	0.3	3.0	2.5	1.0	2.0	7.3	0.7	1.0	1.7	2.5
1983	582.3	2251.3	107.5	1.0	15.0	18.0	13.5	3.3	1.7	0.0	0.7	0.0	0.0
1984	410.7	1645.0	0.0	0.0	25.0	28.7	0.0	1.3	0.0	0.7	0.0	0.0	0.0
1985	263.0	3651.0	0.3	0.0	1.0	3.5	0.5	0.3	0.0	0.0	0.0	0.0	0.5
1986	148.6	66.5	0.5	0.0	0.0	0.5	0.0	0.0	0.3	0.3	0.5	0.0	0.0
1987	82.7	2516.7	1.5	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0
1988	107.0	315.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1989	-	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1990	-	-	2.0	-	-	-	-	-	-	-	-	-	-

* Stations are as follows: South Canadian River near Bridgeport, Blaine Co. (1) and at Calvin, Hughes Co. (2); North Canadian River near Turpin, Beaver Co. (3) and at Woodward, Woodward Co. (4), Cimarron River near Englewood, Harper Co., Kansas (5), Cleo Springs, Major Co. (6), Dover, Kingfisher Co. (7), and Perkins, Payne Co. (8); Salt Fork of the Arkansas River near Jet, Alfalfa Co. (9) and near Nash, Grant Co. (10); Arkansas River near Ralston, Pawnee/Osage Co. (11), at Sand Springs, Tulsa Co. (12), and near Sallisaw, LeFlore Co. (13).

** All collections were made by J. Pigg and reported either in his field notes or in unpublished annual summaries made available by the Oklahoma Department of Health. Values shown are the averages in instances where a site was sampled more than once in a year. See Appendix B for exact locations, numbers of collections per year, numbers of specimens verified and catalogued into the Oklahoma State University Collection of Vertebrates, and numbers reported by Pigg.

Figure 2. Maximum monthly discharge in May through August at two sites in the Cimarron River during the years 1977-1987. Values above each curve represent the maximum for each four-month interval.


WAYNOKA
PERKINS
MAXIMUM MONTHLY DISCHARGE (CFS)
(MAY TO AUGUST)
100,000
10,000
1 000
100
10
7 620
7 880
25 300
3 080
5 880
4 410
5,890
347
1 560
368
9,360
43 100
23,200
16 400
48 600
5 630
67 200
40 900
1 580
11 100
11 900
60 300
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
YEAR

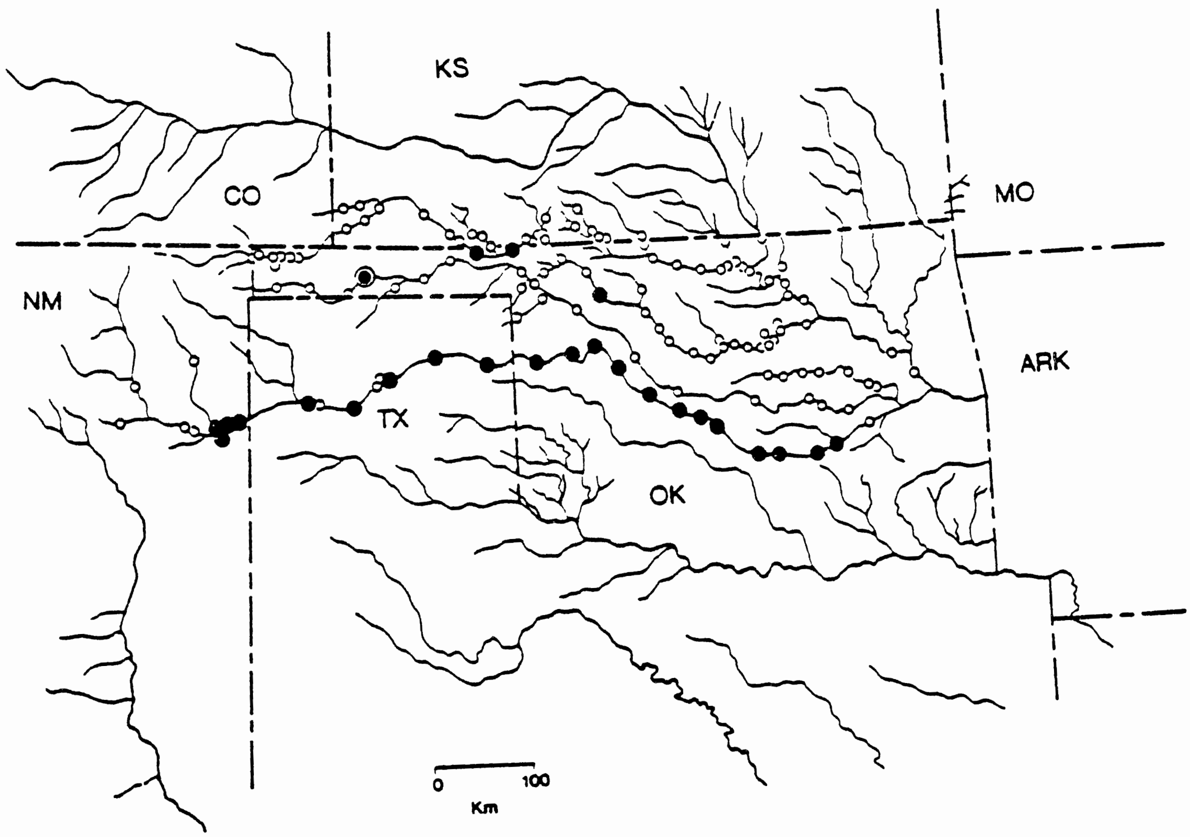
(May-August--see below). At both sites, the maximum flows in 1984 were smaller than in any year between 1977-1987 and were among the smallest maxima recorded for May-August in several decades. Depressed maximum flows for May-August continued into 1985 and 1986 at both sites in the Cimarron. This was most pronounced at Waynoka where the values for 1984 and 1986 were 1 to 2 orders of magnitude smaller than in any other year during 1938-1988.

Although not plotted, depressed May-August maximum discharges also occurred in 1984 at most other sites we examined in the Arkansas River drainage. The values for 1984 were the smallest recorded for the 11-year period (1977-1988) at three sites on the South Canadian River (Canadian, TX; Bridgeport and Calvin, OK) and two sites on the Salt Fork of the Arkansas (Jet and Tonkawa). In the South Canadian River at Bridgeport, the maximum flows in May-August 1984 and 1985 were lower than in all years except one (1970) from 1945 to 1987. The only other sites examined were from the North Canadian River where the 1984 values at two sites (Woodward and Canton) were the second lowest of the 1977-88 period; at a third site (near Wetumka), the 1984 values were not lower than in most other years.

Occurrences in 1989-1991

Figure 3 shows the locations we sampled in 1989-91 in the northern half of Oklahoma, the panhandle of Texas, northeastern New Mexico and southwestern Kansas. Our survey

Figure 3. Occurrences of Arkansas River shiner in collections made in 1989-1991. Large circle with black center represents occurrence of the species in a 1990 collection by J. Pigg. Remainder of symbols represent collections made by Oklahoma State University personnel; closed circles signify occurrences of the shiner. Not shown are about 60 additional collections (sorted and catalogued) made during this period from the Arkansas River system of Oklahoma by Pigg. None of these collections contained the shiner.


KS
CO
MO
NM
ARK
TX
OK
0
100
Km

resulted in 159 collections from 128 localities.

The Arkansas River shiner was common in the South Canadian River upstream from Lake Eufaula. We collected 1452 specimens at 20 of the 29 sites sampled in the South Canadian and its tributaries. The mean abundance for the twenty sites where the Arkansas River shiner occurred was 72 with a range of 2-185 specimens. A collection 10.3 km upstream from Lake Eufaula failed to produce any specimens. The farthest downstream collection of this species was taken 54 km upstream from Lake Eufaula, 1.7 km north of Calvin, Hughes Co., OK. The farthest upstream site was from south of Logan, Quay Co., NM, 5.2 km below Ute Reservoir. None of the five collections made above Ute Reservoir produced specimens of the Arkansas River shiner. Records from Eastern New Mexico University (ENMU) indicate that the Arkansas River shiner was present above Ute and Conchas reservoirs as late as 1977 (Appendix A).

Seventy-three collections were made in the Cimarron River drainage. No Arkansas River shiners were collected from the nineteen sites (six of which were dry) in Kansas. Sampling in Kansas included collections from the Crooked Creek and Bluff Creek tributaries of the Cimarron River. These spring-fed creeks generally have permanent flow. Three collections in the Cimarron River in Oklahoma produced single specimens of the Arkansas River shiner. Two of the collections were made in 1989, one from 8 km south of Waynoka, Woods Co., OK (OSUS 18153, 19 mm SL) and the other from 9.7 km west and 9.7 km north of Knowles, Beaver Co., OK (OSUS 18221, 36 mm SL). Two subsequent attempts at the Waynoka site (in 1990) and three at the Knowles site (one in 1990, two in 1991) failed to produce additional specimens. A third specimen was collected in 1990, 20 km NNW of Rosston, Harper Co., OK (OSUS 19117, 36 mm SL). The species was absent from other samples at this site made in 1989 and in 1991.

The Arkansas River shiner was absent in our collections from 26 sites on the North Canadian River and its tributaries (Deep Fork, Wolf, Clear, and Palo Duro creeks). However, J. Pigg (personal communication) collected four specimens from the North Canadian at U.S. Highway 83 south of Turpin, Beaver Co., OK on 17 July 1990. These specimens are being catalogued in the Oklahoma State University Collection of Vertebrates. Other than those four specimens, the shiner has not been reported from the North Canadian River since 1987, despite annual sampling by Pigg and our own survey of the drainage in 1989. The Arkansas River shiner was absent in our collections from 23 sites on the Salt Fork of the Arkansas River.

Historical Patterns in River Discharge

The flow duration curves across the three historical periods (1949 and earlier, 1950-1969, and 1970-1988) revealed that the South Canadian resembled the North Canadian and Cimarron rivers in two aspects (Appendix C).

At the localities farthest upstream (i.e., the western-most sites), the 75th and 90th percentiles of mean daily discharge were lower in 1970-88 than in the two preceding historical periods, and at the sites farthest downstream, those percentiles were higher than those for one or both of the earlier periods.

At the downstream-most sites in all four rivers we examined, flow levels remained about the same or increased in 1970-1988 relative to the two earlier periods--all of the 1970-1988 percentiles were higher than the corresponding percentiles for one or both of the earlier periods. This applied to all three sites on the mainstem of the Arkansas River, all of which are well removed from the headwaters.

The most notable monthly difference among the three historical periods is a tendency at most sites for high flows to be depressed during the warm months (May-September) of 1970-1988 relative to those months in the other two periods we examined (Figs. 4-7). The Mann-Whitney tests suggested that high flows in 1970-1988 were significantly lower than those in 1939-1949 during May, June, July, and August at Canadian (South Canadian River), June, July, and August at Calvin (South Canadian River), June, July, and September at Woodward (North Canadian River), and June and July at Waynoka (Cimarron River). Comparisons of 90th percentile values in 1970-1988 with the values in 1950-1969 at these sites indicated significant differences during July and August (Canadian), July (Woodward), and July and August

Figure 4. Monthly 10th and 90th percentiles of mean daily discharge for three periods of time at three sites in the South Canadian River. In each panel, the lower set of lines represents the 10th percentile; the upper set represents the 90th.

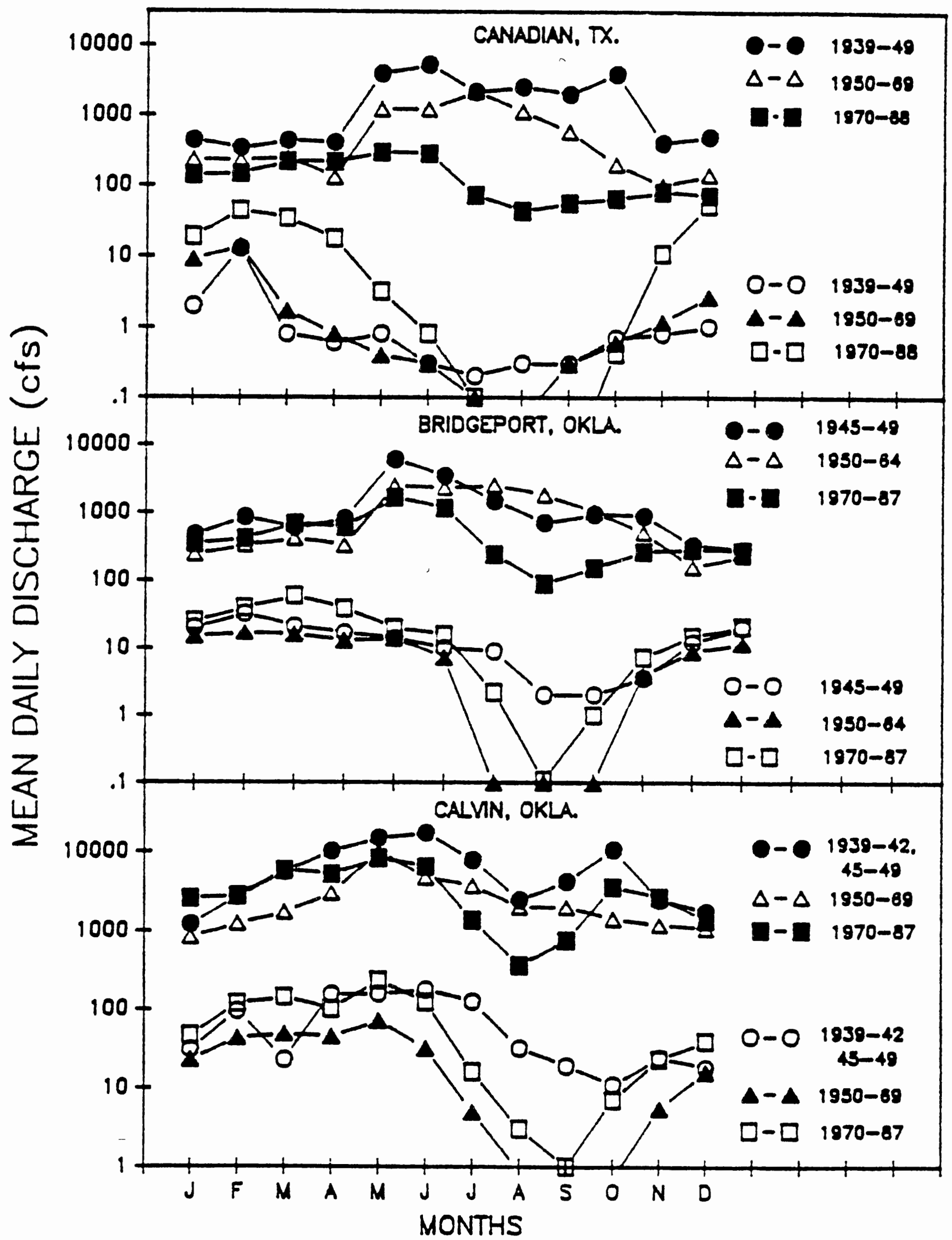
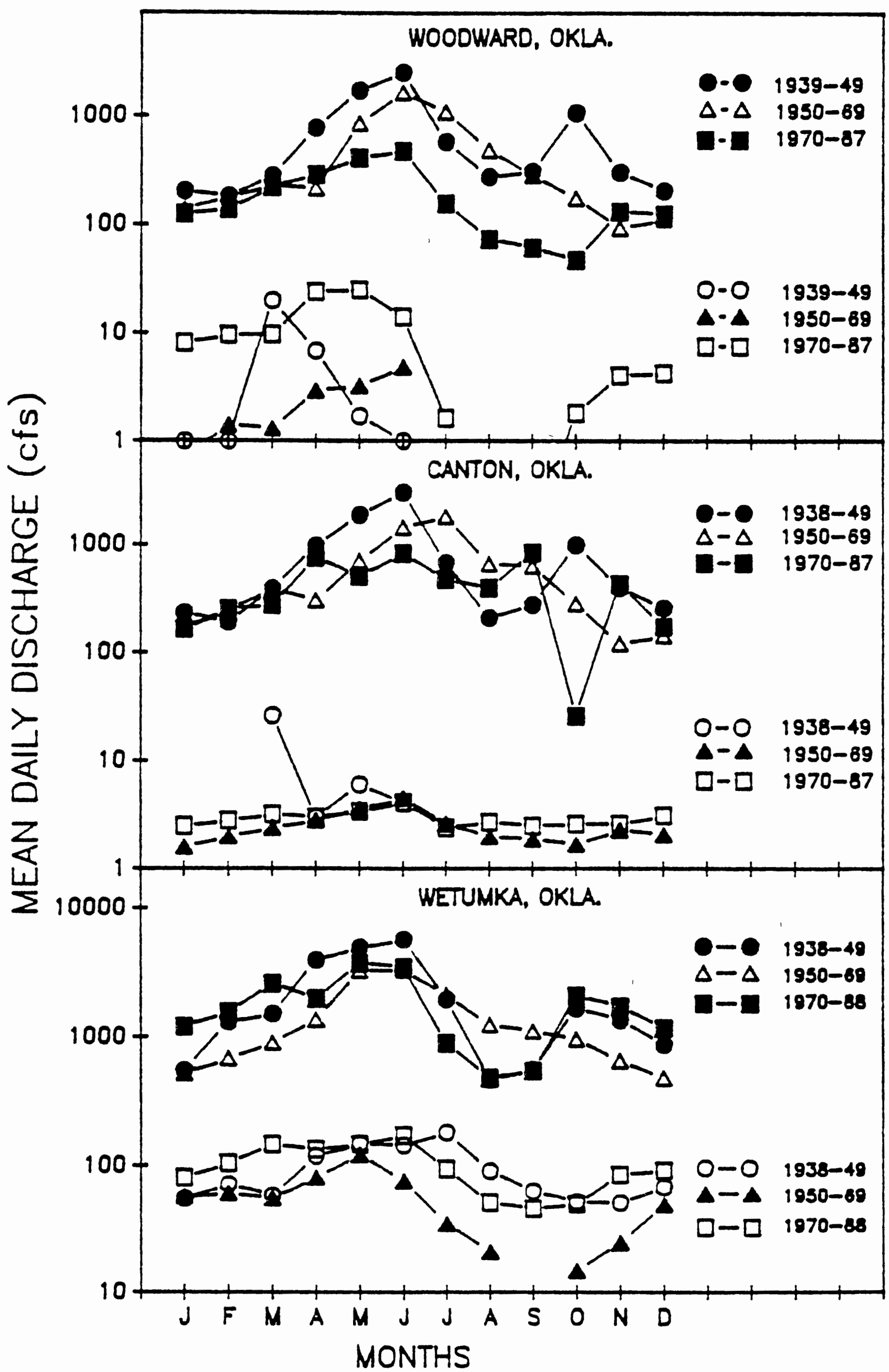

CANADIAN, TX.
BRIDGEPORT, OKLA.
CALVIN, OKLA.
MEAN DAILY DISCHARGE (cfs)
MONTHS
J F M A M J J A S O N D
10000
1000
100
10
1
.1
1939-49
1950-69
1970-88
1945-49
1950-64
1970-87
1939-42,
45-49
1950-69
1970-87

Figure 5. Monthly 10th and 90th percentiles of mean daily discharge for three periods of time at three sites in the North Canadian River. In each panel, the lower set of lines represents the 10th percentile; the upper set represents the 90th percentile.



WOODWARD, OKLA.
1939-49
1950-69
1970-87
1939-49
1950-69
1970-87
CANTON, OKLA.
1938-49
1950-69
1970-87
1938-49
1950-69
1970-87
WETUMKA, OKLA.
1938-49
1950-69
1970-88
1938-49
1950-69
1970-88
MEAN DAILY DISCHARGE (cfs)
10000
1000
100
10
1
J F M A M J J A S O N D
MONTHS

Figure 6. Monthly 10th and 90th percentiles of mean daily discharge for three periods of time at three sites in the Cimarron River. In each panel, the lower set of lines represents the 10th percentile; the upper set represents the 90th percentile.

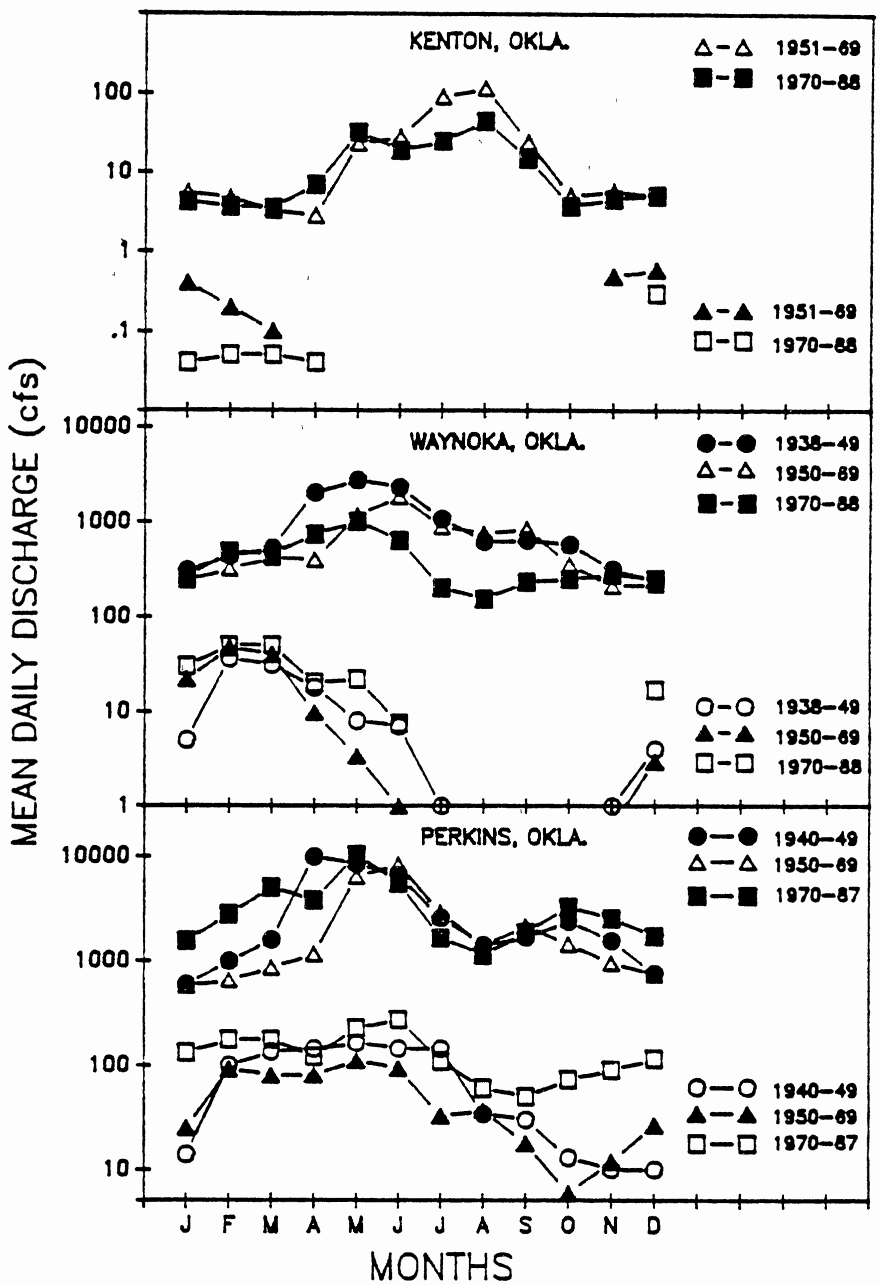
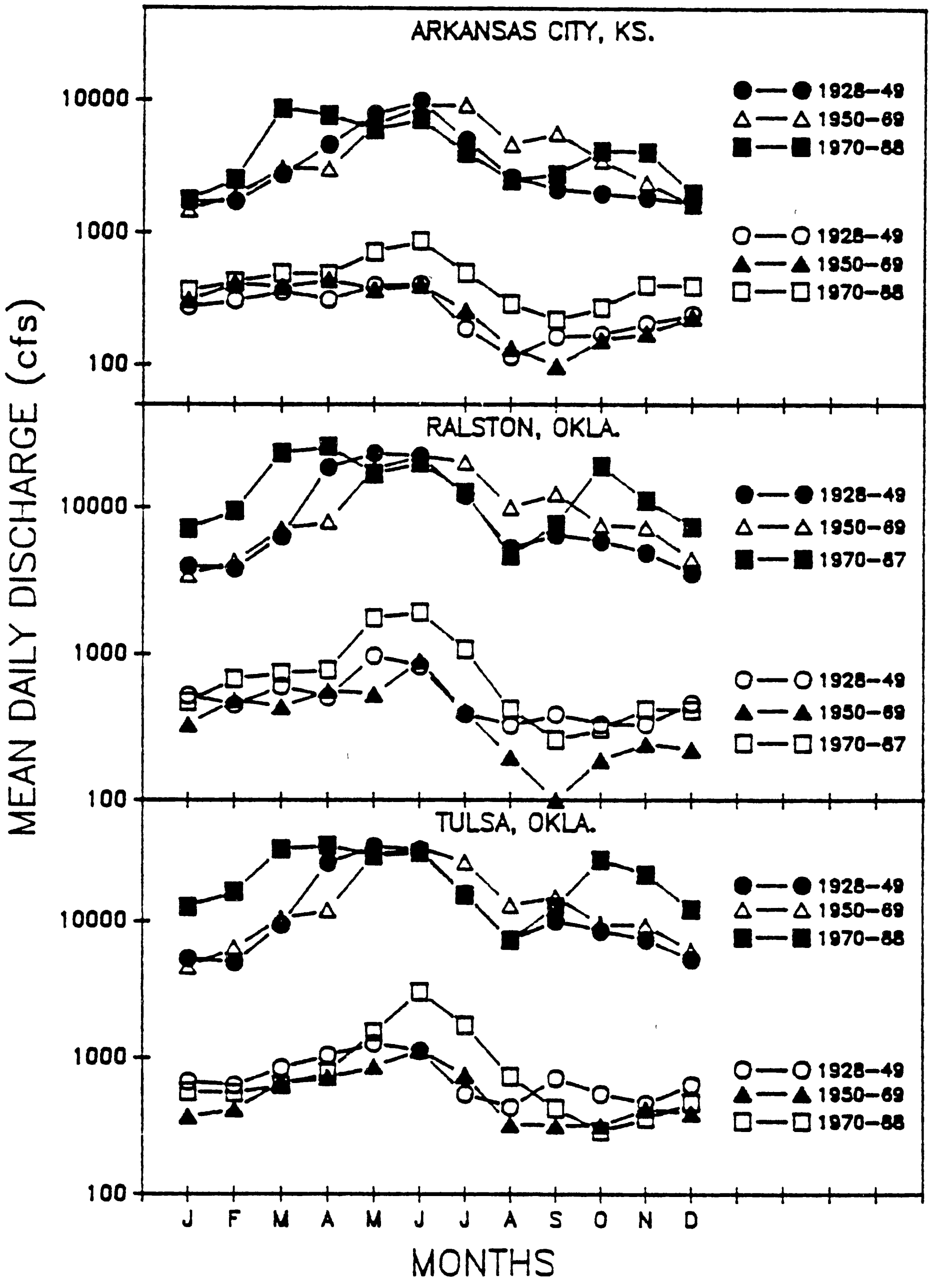

KENTON, OKLA.
Δ–Δ 1951–69
■–■ 1970–88
▲–▲ 1951–69
□–□ 1970–88
WAYNOKA, OKLA.
●–● 1938–49
Δ–Δ 1950–69
■–■ 1970–88
O–O 1938–49
▲–▲ 1950–69
□–□ 1970–88
PERKINS, OKLA.
●–● 1940–49
Δ–Δ 1950–69
■–■ 1970–87
O–O 1940–49
▲–▲ 1950–69
□–□ 1970–87
MEAN DAILY DISCHARGE (cfs)
100
10
1
.1
10000
1000
100
10
1
10000
1000
100
10
J F M A M J J A S O N D
MONTHS

Figure 7. Monthly 10th and 90th percentiles of mean daily discharge for three periods of time at three sites in the Arkansas River. In each panel, the lower set represents the 10th percentile; the upper set represents the 90th percentile.


ARKANSAS CITY, KS.
RALSTON, OKLA.
TULSA, OKLA.
MEAN DAILY DISCHARGE (cfs)
10000
1000
100
1928-49
1950-69
1970-88
1970-87
J F M A M J J A S O N D
MONTHS

(Waynoka).

The only other significant monthly differences involving 90th percentile flow levels among the three historical periods were the following: Canadian (January and February, 1970-1988 < 1939-1949), Perkins (April, 1950-1969 < 1940-1949), and Arkansas City (September, 1950-1969 < 1928-1949). Seventeen of 21 significant differences (81%) among monthly high flows involved depressed flow levels during the warm months of 1970-1988.

The depressed high flows in the warm months of 1970-1988 were not reflected by a similar trend in low flows (Figs. 4-7). Indeed, in instances where the monthly distributions were significantly different between historical periods, the difference usually involved higher flows in 1970-1988, as follows: Canadian (South Canadian River--both early periods lower in February, March, April, 1950-1969 also lower in May); Bridgeport (S. Canadian River--both early intervals lower in March and April); Canton (N. Canadian River--both early periods lower in March, August and September, 1950-1969 also lower in October and December). There were only two other significant monthly differences involving low flows: Kenton (Cimarron River--1951-1969 higher than 1970-1988 in December) and Tulsa (Arkansas River--1928-1949 higher than 1970-1988 in October).

River Conductivity and Occurrences of Arkansas River Shiner

Figures 8-11 show the monthly 10th and 90th percentiles of conductivity records for different intervals of time at several localities within the historical range of the Arkansas River shiner.

The most conspicuous differences between conductivity in the most recent period compared with earlier times occurred in the North Canadian River at Wetumka and at the two sites on the mainstem of the Arkansas River (Arkansas City and Ralston). For both the 10th and the 90th percentiles at all three of those sites, the period from 1970 to the most recent year analyzed showed a decrease in conductivity during all (90th percentile) or most (10th percentile) months. Furthermore, decreases in seasonal variation in the 90th percentiles of conductivity occurred at both Wetumka and Arkansas City. These changes apparently result from increased freshwater input from municipalities (i.e., Wichita, Kansas on the Arkansas River and Oklahoma City on the North Canadian River).

No obvious relationship exists between conductivity and the occurrence of the Arkansas River shiner. Conductivities in the South Canadian River, where the species remains abundant, are comparable to those where the species has declined or disappeared (e.g., the Arkansas River). Historically, the species was abundant in the relatively saline waters of the Cimarron River at Perkins where the

Figure 8. Monthly 10th and 90th percentiles of daily conductivity measurements for two periods of time at two sites in the South Canadian River.

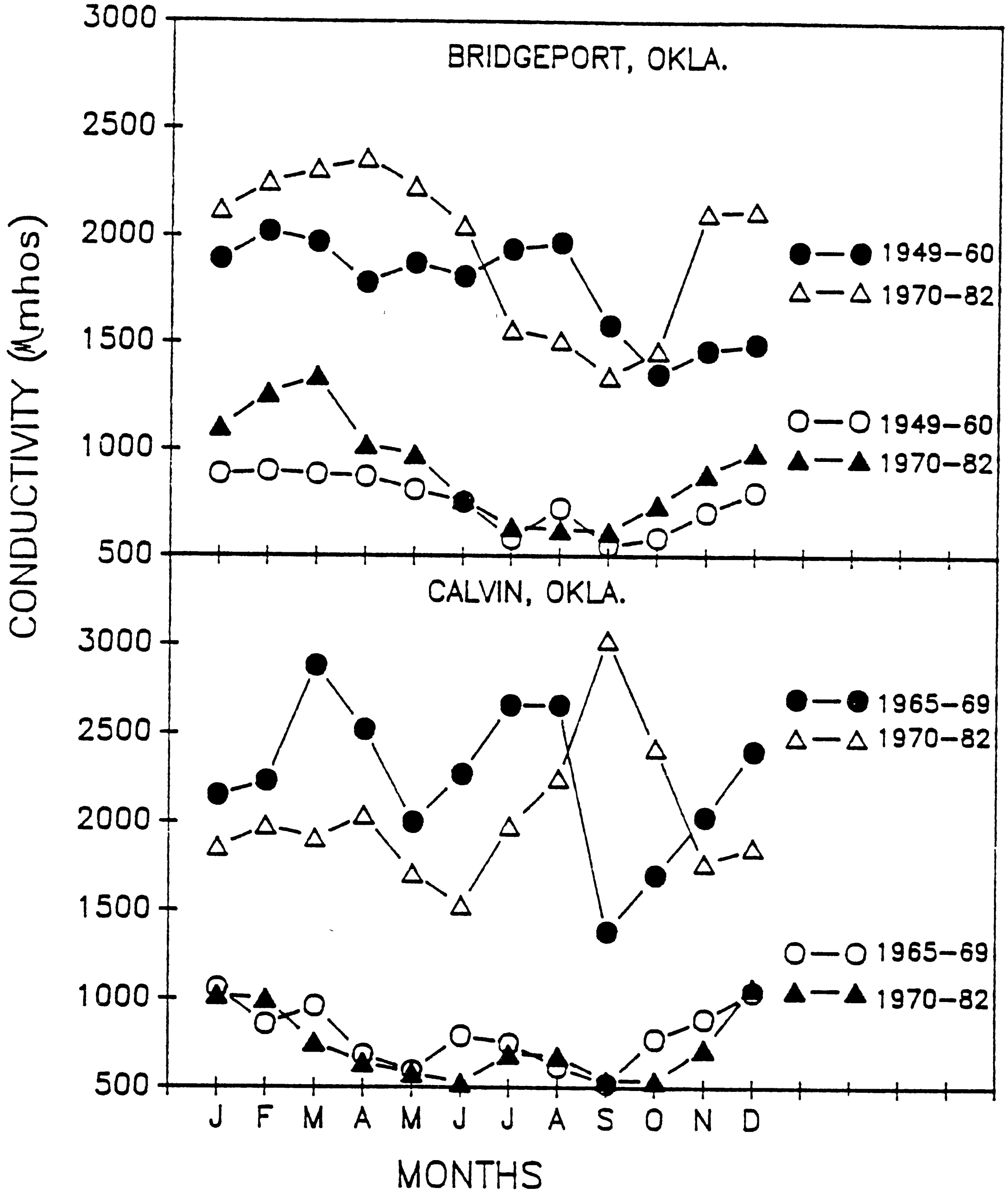

BRIDGEPORT, OKLA.
CALVIN, OKLA.
CONDUCTIVITY (μmhos)
3000
2500
2000
1500
1000
500
1949-60
1970-82
1949-60
1970-82
1965-69
1970-82
1965-69
1970-82
J F M A M J J A S O N D
MONTHS

Figure 9. Monthly 10th and 90th percentiles of daily conductivity measurements for two periods of time at a site in the North Canadian River.

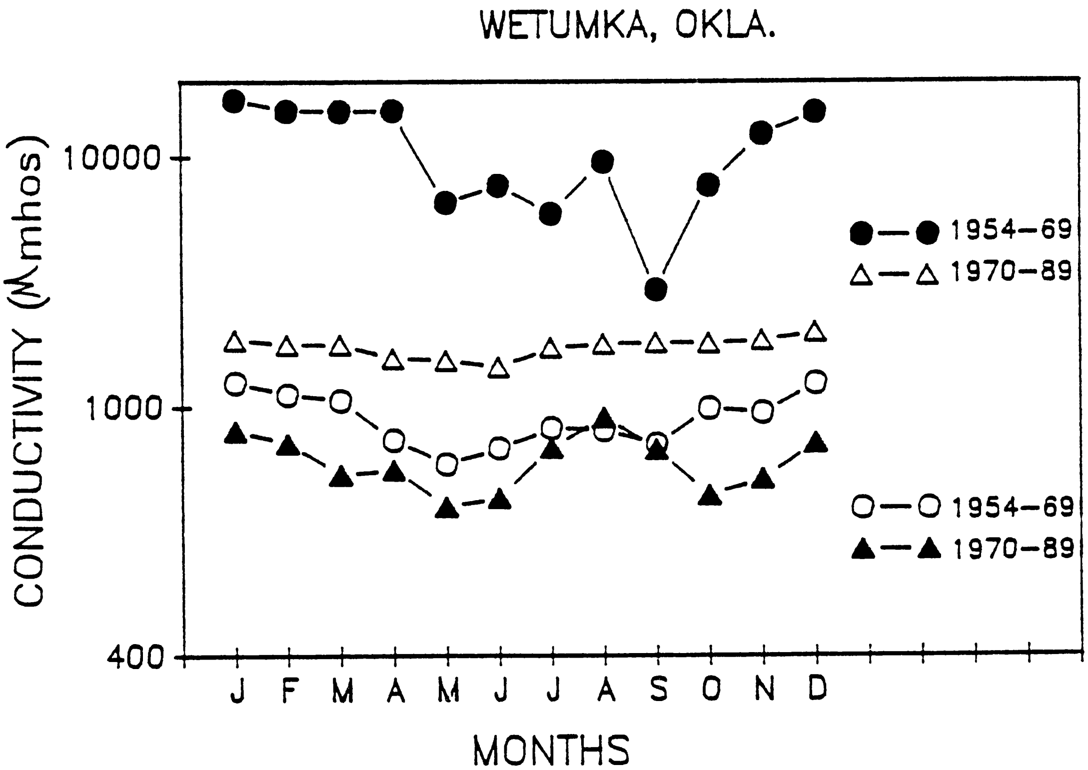

WETUMKA, OKLA.
CONDUCTIVITY (µmhos)
10000
1000
400
1954-69
1970-89
1954-69
1970-89
J F M A M J J A S O N D
MONTHS

Figure 10. Monthly 10th and 90th percentiles of daily conductivity measurements for two periods of time at a site in the Cimarron River.

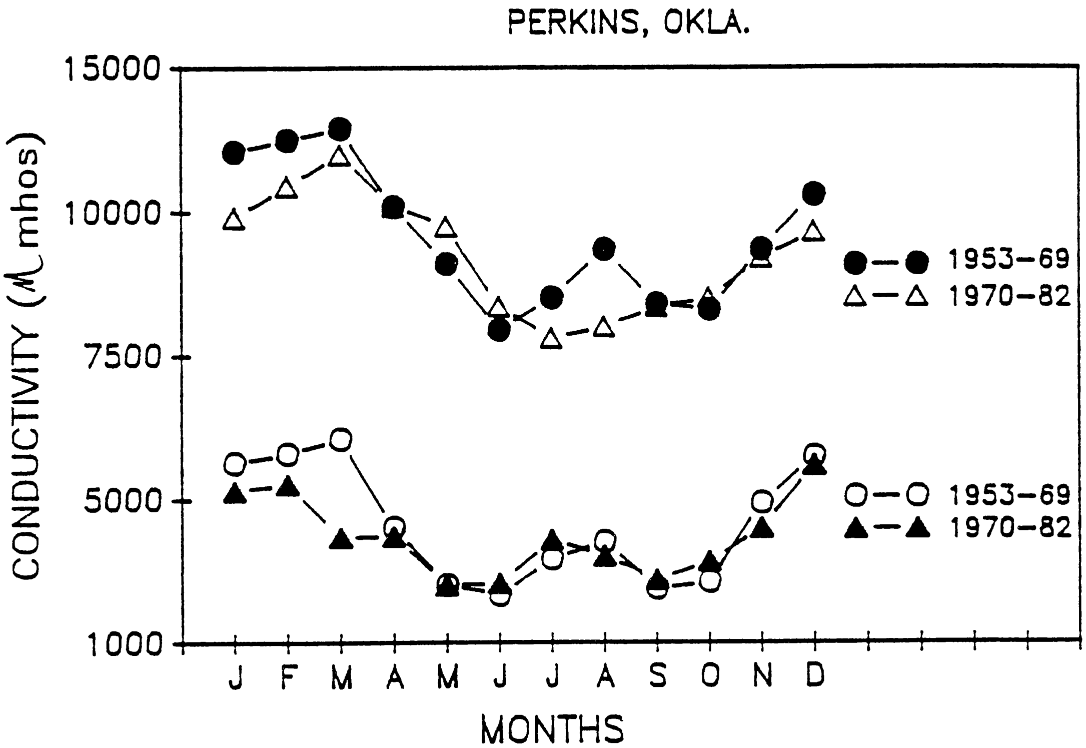
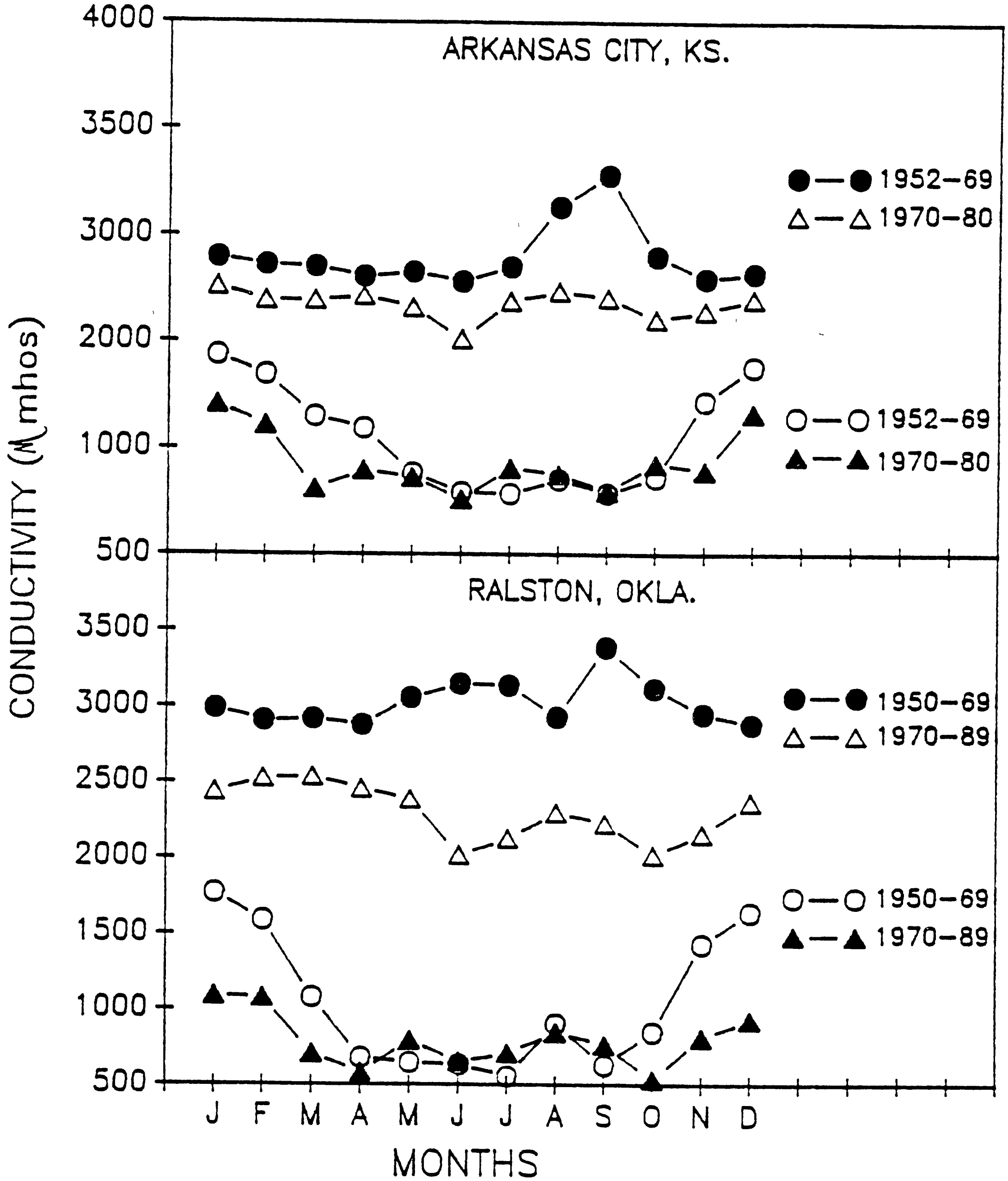

PERKINS, OKLA.
15000
10000
7500
5000
1000
CONDUCTIVITY (μmhos)
1953-69
1970-82
1953-69
1970-82
J F M A M J J A S O N D
MONTHS

Figure 11. Monthly 10th and 90th percentiles of daily conductivity measurements for two periods of time at two sites in the Arkansas River. on the Arkansas River



ARKANSAS CITY, KS.
RALSTON, OKLA.
CONDUCTIVITY (μmhos)
MONTHS
J F M A M J J A S O N D
4000
3500
3000
2000
1000
500
2500
1500
1952–69
1970–80
1952–69
1970–80
1950–69
1970–89
1950–69
1970–89

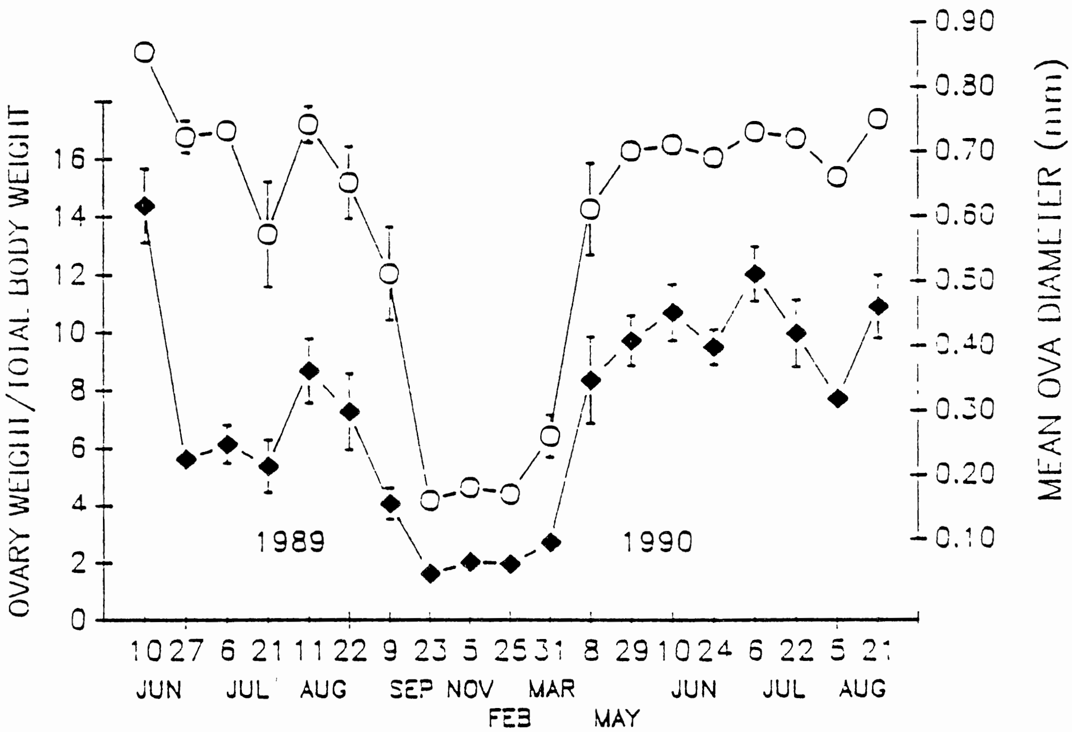
90th percentile of conductivity was often in excess of 10,000 micromhos/cm, and it thrived in the Salt Fork of the Arkansas River where conductivities in excess of 20,000 micromhos/cm were not uncommon. The species remains abundant in the South Canadian River where the 10th percentiles were often an order of magnitude lower.

Reproductive Condition versus Stream Discharge

Based on gonadosomatic index (GSI) and mean ovum diameter, the reproductive season of the Arkansas River shiner extends from about early May to August (Fig. 12). The highest GSI observed in the two years of this study occurred in early June of 1989 when several peaks in river discharge and the highest flows observed during the reproductive seasons of the two years occurred (Fig. 13). The high reproductive condition in 1989 was followed by a marked decline until early August when a smaller peak in reproductive condition was observed. The decline coincided with a period of declining flow levels. The August resurgence in reproductive condition was associated with several large peaks in river discharge.

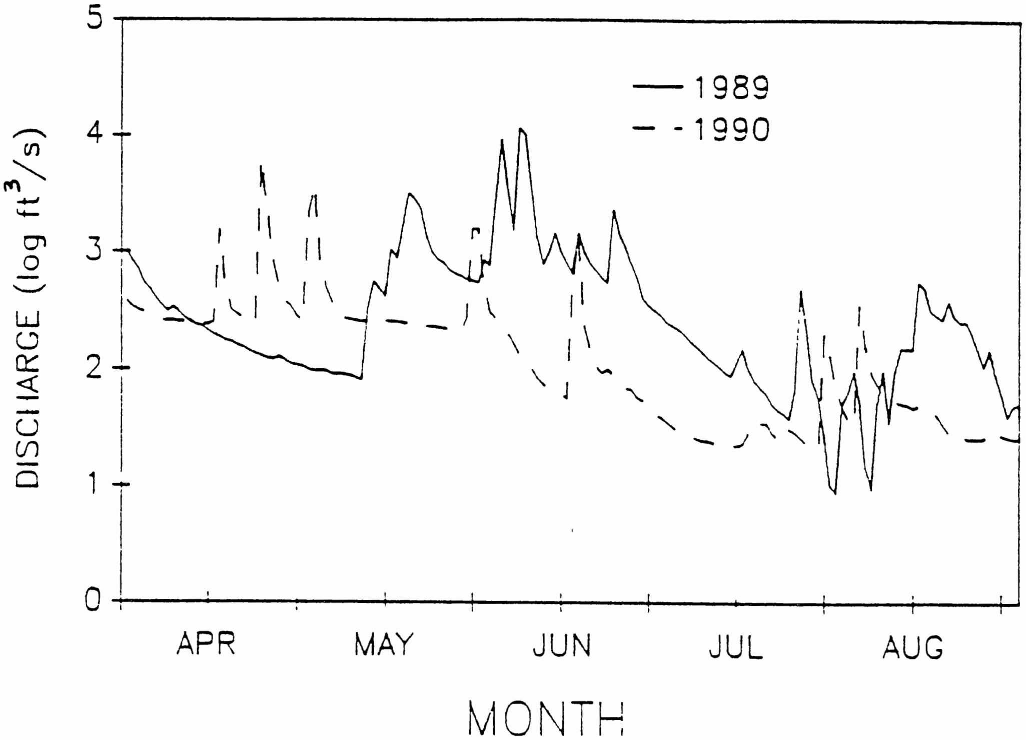
The general pattern of river discharge in 1990 resembled that in 1989 except that the peaks of discharge at the beginning and end of the reproductive season were less frequent and lower in magnitude, especially at the beginning of the season (May-June). Correspondingly, levels of flow in 1990 were lower throughout most of the reproductive

Figure 12. Mean and standard errors of ovum diameter and gonadosomatic index values for Arkansas River shiner in the South Canadian River. Solid diamonds = GSI; Open circles = mean ova diameter.



OVARY WEIGHT/TOTAL BODY WEIGHT
MEAN OVA DIAMETER (mm)
0
2
4
6
8
10
12
14
16
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1989
1990
10 27 6 21 11 22 9 23 5 25 31 8 29 10 24 6 22 5 21
JUN
JUL
AUG
SEP
NOV
FEB
MAR
MAY
JUN
JUL
AUG

Figure 13. Mean daily discharge rates for two years in the South Canadian River at Bridgeport.


1989
1990
5
4
3
2
1
0
DISCHARGE (log ft³/s)
APR
MAY
JUN
JUL
AUG
MONTH

season. Perhaps as a result, reproductive condition in 1990 did not reach the maximum seen in June of 1989. At the same time, however, the 1990 season was not characterized by the marked midsummer decline in reproductive condition that occurred in 1989. Instead, high levels of reproductive condition were sustained throughout the 1990 season. The plateau in reproductive condition in 1990 may have reflected restrained spawning activity resulting from the relatively low frequency of high flows. In contrast, the midsummer decline in 1989 may have reflected depletion of ovaries during a burst of spawning activity early in the season.

Possible Effects of Commercial Bait Harvesting

The Oklahoma Department of Wildlife Conservation report for 1989 shows that 49 commercial minnow dealer licenses were issued in that year. A total of 91,354 pounds of minnows were seined from Oklahoma waters. The following amounts were removed from rivers within the historic range of Arkansas River shiners (parentheses show percent of total harvest from Oklahoma): South Canadian River, 23,960 pounds (26.2%); Cimarron River, 18,253 pounds (20.0%); Salt Fork of the Arkansas River, 360 pounds (0.4%); and North Canadian River, 739 pounds (0.8%). The species reported are predominantly plains minnows (85% statewide), golden shiners (13%), gizzard shad (0.01%), and crayfish (0.01%). This list may be somewhat suspect as we encountered no locality where golden shiners comprised such a high proportion of the collection.

The fish listed in the bait harvest report are predominantly large-sized species, and it is likely that large-mesh seines are the major mode of capture. The Arkansas River shiner is a small, slender-bodied species (generally less than 50 mm total length). Thus, it seems likely that relatively few would be included in the commercial harvest. There is no evidence from historical collections to indicate that the shiner has declined in the South Canadian River, the drainage supporting the majority of the harvest from the Arkansas River system.

Possible Effects of Turbidity

We did not do a detailed analysis of turbidity levels in the Arkansas River drainage. Turbidity records at the sites we examined extended only into the 1970s when the Arkansas River shiner had already started to decline.

As a group, native plains minnows like the Arkansas River shiner exhibit a variety of sensory and reproductive adaptations to extreme turbidities (Cross and Moss 1987). Cross and Moss (1987) suggested that in some stream reaches of Kansas the native plains fishes have been replaced by sight-feeding planktivores and piscivores adapted to clear, moderately flowing waters and reservoirs. This effect is difficult to assess. In Oklahoma, there seems to have been an increase in the abundance of red shiners, inland silversides and bullhead minnows, particularly in downstream areas. In part, this may be due to decreased turbidities resulting from reduced flows and reservoir construction.

CHAPTER IV

DISCUSSION

Current Status of Arkansas River Shiner

Our findings support the conclusion by Pigg (in press) and Cross et al. (1985) that the Arkansas River shiner has disappeared from a large portion of its former range. Within its historical range, the species now appears primarily restricted to the South Canadian River between Ute Reservoir in eastern New Mexico and Lake Eufaula in eastern Oklahoma, a river-distance of approximately 900 kilometers. A large, introduced population does occur, however, in the Pecos River drainage of New Mexico (Bestgen et al., 1989).

The only other post-1988 evidence for extant populations of the species consists of five collections of 1-4 specimens each in 1989-1990 from the North Canadian and Cimarron rivers in the panhandle region of Oklahoma. Pigg (personal communication) observed bait dealers flushing out their transport tanks in the vicinity of the site where the 1990 collection of four specimens was taken from the North Canadian River. Thus, the possibility exists that the specimens in question were artificially transported from the South Canadian River.

A small population of the Arkansas River shiner occurred in a 160-kilometer reach of the upper Cimarron River as recently as August 1990 (Fig. 3). During 1989-1990, we made three collections of one specimen each from three Oklahoma sites in that reach of the river. The last collection was from a locality just across the state line from Englewood, KS in Oklahoma. The last reported collection of the species from Kansas was also from the upper Cimarron River; Eberle et al. (1989) reported a single specimen from Morton County. Pigg also collected a single specimen from south of Englewood in Oklahoma on 24 April 1988 (Appendix B).

A small population may persist in the upper Cimarron in the vicinity of Englewood and areas immediately downstream, although we failed to collect it from the region in 1991. A number of spring-fed tributaries converge with the Cimarron River in its upper reaches (e.g., Crooked Creek near Englewood and Eagle Chief Creek near Cleo Springs), and this may help explain the persistence of the species in this area. Cross et al. (1985) characterized Crooked Creek as having flows "sustained by marshy seeps and springs." They also noted that, although flows in Crooked Creek have decreased slightly at the 10th and 90th percentiles of daily discharge, the high, natural variability in discharge remained. Consequently, Cross et al. (1985) suggested that the species might use Crooked Creek for spawning purposes.

No specimens of Arkansas River shiner have been collected from the Arkansas River or from the Salt Fork of the Arkansas River since 30 June 1987. On that date, J. Pigg made a collection of 1 specimen (OSUS 19952) from the Salt Fork of the Arkansas River near Jet, Alfalfa Co.

Within the South Canadian River, the Arkansas River shiner apparently has disappeared from Lake Eufaula eastward (Pigg, in press). The species remains abundant westward from Lake Eufaula, with an occasional collection containing thousands of specimens. Beyond this observation, little can be said regarding trends in population densities of the extant populations in the South Canadian River drainage.

Possible Causes of Decline

In most parts of its range, the Arkansas River shiner has been declining in both geographic distribution and local abundances since at least the mid 1970s (Lindsay and Cheek 1973; Felley and Cothran 1981; Cross et al., 1985). In an early comment regarding the decline of the species, Lindsay and Cheek (1973) stated that, formerly, the Arkansas River shiner "occurred in abundance [along a stretch of the river between Tulsa and Muskogee]. Now it is very rare to find one specimen . . . in a sample." They attributed the decline to closing of Keystone Dam (in 1964) "and possibly a time of increased pollution. . ." Robison and Buchanan (1988) suggested that, by 1971, the McClellan-Kerr Navigation System downstream from Tulsa probably had contributed toward extirpation of the species in Arkansas. Direct effects of inundation and altered flows due to reservoir construction have undoubtedly contributed to local declines of the species throughout its range.

Our analyses of flow duration curves and monthly 90th percentiles of river discharge in western Oklahoma agree with the findings of Cross et al. (1983; 1985). Cross and Moss (1987) attribute this to dams and irrigation practices (diversion canals and groundwater pumping primarily). In the North Canadian River (Beaver River) near Guymon, Wahl and Wahl (1988) found that annual average flow, annual base flow, and annual peak discharge were much lower in 1977-1986 than in earlier times. They attributed this primarily to a large increase, between 1963 to 1984, in the number of "large-capacity wells (primarily irrigation wells)" in the Oklahoma Panhandle.

Based largely on Moore's (1944) brief observations, it has generally been assumed that the Arkansas River shiner depends on midsummer floods for successful spawning (e.g., Bestgen et al., 1989). Cross et al. (1985) gave the following summary of Moore's (1944) findings and their own observations: "females develop 1500-3500 eggs of uniform size in spring, but retain them until water levels rise abruptly . . . . The bouyant eggs drift on strong currents in midstream for 2-4 days to hatching. Little else is known of the spawning behavior or of movements by the young or adults." Cross et al. (1985) speculated that, after hatching, the young "must return upstream to restore populations at the original spawning sites." According to this model, flooding in upstream reaches is essential for survival of the shiner throughout the rivers it occupies, including many areas where spawning may not occur.

Cross et al. (1985) suggested that the full complement of eggs are spawned at flood stage, whereas Bestgen et al. (1989) found length-frequency evidence for multiple spawnings in New Mexico populations. Bestgen et al. (1989) suggested that the success of the introduced population in the Pecos River was due to irrigation practices in which water stored in large reservoirs is occasionally released during the spawning season, providing the "pulses of discharge" required for reproduction.

Two observations from our study support the concept that peak flows are important to the success of the species; 1) The 1983-1985 decline of the species in Oklahoma was associated with unusually low maxima of river discharge throughout the reproductive season (May-August) in 1984. In the Cimarron River, depressed peak flows during those months also occurred in the two years subsequent to 1984. Although the breeding populations of the species may include 3 to 4 year classes of adults, Age I is the predominant age class (Cross et al. 1985; Bestgen et al. 1989). Thus, even one year of suppressed spawning would have a large effect. 2) Our analysis of ovarian condition on the South Canadian River population is consistent with the hypothesis of restrained spawning in a year (1990) of depressed peak flows during the reproductive season. In the previous year, when peak flows during the reproductive season were greater in magnitude and more frequent, a massive spawning apparently occurred early in the season.

Various workers have suggested the possibility that competition with introduced fishes has contributed to the decline of the Arkansas River shiner (Felley and Cothran, 1981; Cross et al. 1983, 1985). Felley and Cothran (1981) especially emphasized the possible effects of introduced Red River shiner (Notropis bairdi), a species that resembles the Arkansas River shiner in general appearnce and ecological requirements. However, Cross et al. (1983, 1985) pointed out that Arkansas River shiner disappeared in areas devoid of Red River shiner. Our collections and those by J. Pigg demonstrate that the introduced populations of Red River shiner in the Arkansas River drainage are confined to the Cimarron River, yet the Arkansas River shiner is no less abundant there than in any other portion of the historic range outside the South Canadian River. Futhermore, the introduced Arkansas River shiner in the Pecos River is thriving in a situation of greater species diversity than it generally encounters in its native range (Bestgen et al., 1989). Nonetheless, it is possible that competition with introduced species has contributed to depressed population densities, thereby making the population more susceptible to effects resulting from other factors, such as altered flow regimes.

The weight of the evidence points to altered flow regimes as the most important drainage-wide cause of the decline of the Arkansas River shiner, with the decline in peak flows possibly being a major factor. However, our data suggest that the decline in peak flows has also occurred in the South Canadian River, yet the species remains abundant throughout most of its former range in that river.

The New Mexico populations in the South Canadian River are in a region of frequent midsummer rains and considerable topographic relief. Thus, pulses in river discharge may be adequate for successful reproduction between Ute Reservoir and Lake Meredith in the Texas panhandle.

At least two factors may explain the success of the shiner in the South Canadian River between Lake Meredith in the Texas Panhandle and Lake Eufaula in eastern Oklahoma. This is the longest stretch of river within the historic range of the species that has not been impounded. Such a stretch of unimpeded flow would enhance the chances of successful local spawns somewhere in the reach and would accommodate the extensive dispersal of eggs and young that Cross et al. (1985) envisioned as being essential for the success of the species. Another possibility is that, because of its southern position relative to all other populations of the species, the South Canadian River populations may breed somewhat earlier in the year, thereby taking advantage of earlier spring pulses in discharge. This effect may help explain why the species disappeared from the Arkansas River in Kansas before it reached its present low levels in Oklahoma.

One final factor must be mentioned regarding the virtual disappearance of the shiner within its historical range outside the South Canadian River. Namely, barriers to upstream migration that prevent the species from repopulating areas where it has been depleted. For example, were it not for downstream barriers (Lake Eufaula, the McClellan-Kerr Navigation System, Keystone Reservoir, etc.) the species might repopulate the other drainages of the Arkansas River system through dispersal from the South Canadian River.

CHAPTER V

CONCLUSIONS

1. The Arkansas River shiner remains abundant in the South Canadian River between Lake Eufaula in eastern Oklahoma and Ute Reservoir in eastern New Mexico.

2. An abundant population of the species occurs in a 300 kilometer stretch of the Pecos River in New Mexico, where it was introduced in the late 1970's, possibly as a result of bait transport.

3. Except for the South Canadian River, the species has effectively disappeared throughout the remainder of its historical range.

4. There is meager evidence that small, remnant populations persist in a small stretch of the upper Cimarron River and at a local area in the North Canadian (Beaver) River.

5. Peak river discharges during May-August appear essential to successful reproduction and dispersal of this species.

6. A decline in the magnitude and frequency of peak flows has occurred throughout much of the historical range of the species. This effect is especially pronounced during the warm months of the year, the reproductive season for the

shiner. The decline in peak flows appears primarily due to reservoir construction and irrigation practices.

7. Similar declines in peak flows have occurred in the South Canadian River where the shiner remains abundant. The continued presence of the shiner in this area is attributable to the following factors: a) The New Mexico population is in an area of frequent midsummer rains and high topographic relief. Thus, peak flows may be adequate to sustain successful reproduction of the species. b) The long, stretch of unimpeded flow between Lake Meredith in the Texas Panhandle and Lake Eufaula in eastern Oklahoma heightens the chances of successful local spawns somewhere in the reach. Such a long reach also accomodates the extensive dispersal of eggs and young that seems essential for the success of the species. c) Because of its southern position relative to all other populations of the species, the South Canadian River populations may breed somewhat earlier in the year, thereby taking better advantage of late spring pulses in discharge, even in low flow years.

8. The Arkansas River shiner was consistently taken, although typically in low numbers, in the North Canadian and Cimarron rivers and in the Salt Fork of the Arkansas River until 1983. By 1984-1986, abundance of the species in those drainages had declined to the present low levels.

9. The mid-1980's decline in abundance of the species was associated with a severe drought in 1984. The 1984 May-August monthly maxima in river discharge rates were among

the lowest encountered in our survey of records as far back as 1938 and 1945.

10. There is no evidence that commercial harvesting of bait minnows has contributed to the decline of the Arkansas River shiner or that it is endangering the shiner in the Arkansas River drainage. One effect of bait-harvesting and transport practices may be the re-introduction of the species into local areas where it has all but disappeared. Although possibly beneficial to the survival of the Arkansas River shiner, uncontrolled releases of other fishes can contribute to the loss of natural patterns of genetic diversity and zoogeography.

CHAPTER VI

RECOMMENDATIONS

1. The Arkansas River shiner should be considered for formal listing as a threatened species in Oklahoma. The species has effectively disappeared from three-fourths of its historical range. The rapidity of disappearance from Oklahoma waters outside of the South Canadian River suggests the potential for similarly rapid declines in existing populations. Historical records indicate that peak river flows are declining in upstream areas of the South Canadian River. Continuation of such declines could lead to the elimination of the species, as peak river flows may be essential for the success of the species.

2. A management plan should be developed for the Arkansas River shiner.

3. A detailed study of the life history of the shiner should be conducted. At present, conclusions regarding dispersal abilities and the relationship between river discharge and reproductive success are largely speculations based on limited information.

4. A detailed study and census of bait-harvesting activities would provide valuable insight into the potential effects of this activity (both positive and negative) on the

Arkansas River shiner, as well as other species of interest.

5. Monitoring of the South Canadian River populations should continue because of the rapidity with which the species has declined in other drainages.

6. Monitoring of remnant populations should continue in the upper reaches of the North Canadian and Cimarron rivers.

7. New water resource developments that reduce stream flows or otherwise alter the natural flow regime should be discouraged or carefully evaluated for potential adverse effects on Arkansas River shiners.

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APPENDIX A

RECORDS OF PAST COLLECTIONS FROM LOCALITIES OF HISTORICAL OCCURRENCE

Location			Date	No.	Cat. #

TEXAS MEMORIAL MUSEUM, UNIVERSITY OF TEXAS (TNHC)

Texas	OK	Canadian River N of Guymon	29 May 49	?	?

MUSEUM OF SOUTHWESTERN BIOLOGY, UNIVERSITY OF NEW MEXICO (MSB)

Harding	NM	Ute Crk., near Bueyeros	21 Feb 51	18	1270
Harding	NM	Ute Crk., S of Bueyeros	24 Aug 39	78	1269
Noble	OK	Skeleton Crk.	29 Mar 49	15	4678
Quay	NM	Revuelto Crk., W of Logan	09 Feb 87	438	4672
Quay	NM	Canadian R. at Logan	23 Aug 39	362	1272
Quay	NM	Tucumcari Crk., S of Logan	23 Aug 39	94	1268
San Miguel	NM	Conchas Lake, near dam	22 Aug 39	533	1267
San Miguel	NM	Conchas R., 20 mi W Canadian R	22 Aug 39	4	1271

EASTERN NEW MEXICO UNIVERSITY, PORTALES (ENMU)

Quay	NM	Canadian R., 1.5 mi E of Logan	30 Sep 74	7	63.04
Quay	NM	Canadian R., 2.5 mi W, 1.5 mi S Logan	08 May 75	42	57.04
Quay	NM	Canadian R., 9 mi E, 1 mi N of Logan	09 May 75	72	61.03
Quay	NM	Canadian R., 17.5 mi E, 1 mi S Logan	09 May 75	68	62.04
Quay	NM	Revuelto Crk., 2 mi E of Logan	25 May 75	65	70.03
Quay	NM	Canadian R., at Logan	30 May 78	9	*29357
Quay	NM	Revuelto Crk., 2 mi SE of Logan	30 May 78	44	WJM279
Quay	NM	Revuelto Crk., 1.5 mi SE of Logan	13 Dec 79	278	9.05
Quay	NM	Revuelto Crk., 1.75 mi SE of Logan	14 Jul 80	49	18.01
San Miguel	NM	Canadian R., 3 mi S, 2 mi E Sabinoso	02 Jun 77	1	62.05

UNIVERSITY OF OKLAHOMA, STOVALL MUSEUM OF ZOOLOGY (UOMZ)

Alfalfa	OK	Salt Plains Reservoir, Fish & Wldlf HQ	01 May 53	25	38172
Alfalfa	OK	Salt Fork of the Arkansas River	- - 48	1	26054
Alfalfa	OK	Salt Fork of the Ark. R. at Ingersoll	11 Jul 26	?	6252
Alfalfa	OK	?	- Mar 51	7	26487
Alfalfa	OK	Sand Crk., Hwy 11 bridge	26 Mar 51	3	36834
Alfalfa	OK	Sand Crk., above reservoir	31 Mar 51	4	36729
Alfalfa	OK	Salt Fork Ark., Salt Plains dam	26 Mar 49	2	36897
Alfalfa	OK	Salt Fork Ark., Salt Plains dam	30 Mar 51	103	36724
Alfalfa	OK	Salt Plains Reservoir	27 Mar 49	4	36868
Alfalfa	OK	Salt Fork Ark., Salt Plains dam	26 Mar 49	5	29159
Alfalfa	OK	Salt Fork of the Ark. R.	20 Jun 30	?	15352
Alfalfa	OK	Pond	13 Jun 30	?	15838
Alfalfa	OK	Salt Fork of the Ark. R.	21 Jun 30	?	15348
Beaver	OK	Beaver R., T4N, R26 S31, 32	18 Jun 63	33	32184
Beaver	OK	T3N, R21E, S6	19 Jun 63	55	32129
Beaver	OK	Beaver R., Beaver T4N, R24E, S7	23 Jun 63	46	32350
Beaver	OK	Clear Crk., T4N, R24E, S23	18 Jun 63	7	32044
Beaver	OK	Beaver R., T4N, R28E, S29, 20	23 Jun 63	43	32536
Beaver	OK	Cimarron R., T6N, R25E, S23	23 Jun 63	47	32529
Beaver	OK	Beaver R., T4N, R26, S31,32	18 Jun 63	69	32234
Beaver	OK	Kiowa Crk., T3N, R28E, S2	17 Jun 63	2	32159
Caddo	OK	S. Canadian R., T12N, R11W, S2	04 May 58	150	36470
Cimarron	OK	W. Carrizzo Crk., 3.5 mi NW Kenton	07 Jul 26	11	6260
Cimarron	OK	Cimarron R., 3 mi NW Kenton	07 Jul 26	90	6211
Cleveland	OK	Canadian R., S of Norman	?	7	5948
Cleveland	OK	Little R., 10 mi E of Norman	30 May 26	4	6217
Cleveland	OK	Canadian R., 4.5 mi SW of Norman	30 Oct 24	100	5946
Cleveland	OK	South Canadian River at I-35	01 May 61	827	31925
Cleveland	OK	South Canadian River at I-35	05 Apr 65	55	33961
Cleveland	OK	South Canadian River below Hwy 9	05 May 58	136	31563
Cleveland	OK	South Canadian River at Noble	- - 34	?	15340
Custer	OK	Little Deer Crk.	04 Apr 60	38	31239
Dewey	OK	South Canadian River at Rt. 34 bridge	15 Mar 78	1	42776
Dewey	OK	Canadian R.	?	?	15356
Dewey	OK	South Canadian River	?	?	15353
Ellis	OK	Spring near mouth of S. Canadian R.	15 Mar 78	1	42771
Ellis	OK	Wolf Crk., T21N, R24W, S3	25 Jun 63	11	32454
Ellis	OK	S. Canadian R., T16N, R22W, S10&11	25 Jul 63	209	32829
Ellis	OK	Clear Crk., T24N, R25W, S9	24 Jun 63	3	32426

Ellis	OK	T18N, R25W, S18	25 Jun 63	233	32769
Ellis	OK	Commission Crk., T18N, R26W, S13	25 Jun 63	93	32568
Grady	OK	Buggy Crk., 0.5 mi NE of Minco	04 Apr 60	237	30376
Harper	OK	Cimarron R., T29N, R26W, S23	23 Jun 63	46	32448
Harper	OK	Beaver R., T26N, R25W, S9	24 Jun 63	163	32470
Harper	OK	Commission Crk., T25N, R24W, S26	24 Jun 63	26	32572
Haskell	OK	Canadian R., T10N, R18E, S28,29	10 Jul 62	8	35017
Hughes	OK	S. Canadian R., Rt. 48, Holdenville	14 Oct 78	23	41748
Hughes	OK	S. Canadian R., Rt. 270 bridge	16 May 79	5	42869
Hughes	OK	S. Canadian R., T7N, R12E, S20	27 Jul 62	940	35336
Kay	OK	Salt Fork Ark. R., S of Ponca City	18 Jun 32	?	15334
Kingfisher	OK	Cimarron R., Rt. 5, E of Okeene	08 Jul 79	1	42685
LeFlore	OK	Arkansas R., SW of Ft. Smith	04 Jul 27	?	7574
Logan	OK	Cimarron R., T17N, R2W, S29	03 May 65	63	33991
Logan	OK	Cimarron R.	25 Jul 29	?	15347
Logan	OK	Cimarron R.	25 Jul 29	?	15339
Major	OK	Barron R., Rt. 60 near Orienta	08 Jul 79	4	42679
Major	OK	Waynoka Dam, NE of Chester	10 Mar 55	29	37432
Major	OK	Cimarron R.	03 May 62	71	33790
Major	OK	Main Crk.	03 May 62	90	34016
Major	OK	Main Crk.	?	?	15345
Major	OK	Eagle Chief Crk.	18 Jul 28	?	15344
Major	OK	Cimarron R., S of Cleo Springs	18 Jul 28	?	15355
Major	OK	Cottonwood Crk., Bitter	?	?	15346
Major	OK	Cimarron R.	28 Jun 30	?	15354
Major	OK	Eagle Chief Crk.	27 Jun 30	?	15341
Marshall	OK	Brian Crk., L/M. W of Texoma	20 Jun 64	31	32672
Marshall	OK	Big Glasses Crk., near mouth	11 May 71	1	40614
McClain	OK	Walnut Crk., Hwy 24. T7N, R3W, S23	05 Sep 83	10	43308
McClain	OK	Walnut Crk., US 77 Purcell	12 Mar 49	10	36831
McClain	OK	Walnut Crk. of Arkansas	28 Jul 32	?	15343
McClain	OK	South Canadian River	28 Jul 32	?	15336
McCurtain	OK	Little Pine Lake, S of Broken Bow	29 Jun 55	10	29714
McIntosh	OK	S. Canadian R., T9N, R16E, S28	13 Jul 62	100	35112
McIntosh	OK	N. Canadian R., T11N, R14E, S28	29 Jun 62	400	34818
McIntosh	OK	N. Canadian R., T10N, R17E, S31	06 Jun 62	2	34388
McIntosh	OK	N. Canadian R.	12 Jun 62	282	34470
McIntosh	OK	N. Canadian R.	12 Jun 62	30	34457
McIntosh	OK	Deep Fork, above mouth	16 Aug 62	5	36106
McIntosh	OK	N. Canadian R., T9N, R17E, S5	13 Jul 62	500	35086
McIntosh	OK	Canadian R., T10N, R17E, S34	16 Aug 62	320	36117
McIntosh	OK	N. Canadian R., above mouth Deep Fork	15 Jun 62	152	34535
McIntosh	OK	Canadian R., E Whitefield bridge	23 Aug 62	68	36235
McIntosh	OK	Canadian R., Rock & Broken Crk.	23 Aug 62	330	36224
McIntosh	OK	Miller Crk., T9N, R15E, S24	27 Jun 62	29	34760
McIntosh	OK	S. Canadian R., T8N, R14E, S7	28 Jun 62	180	34784
McIntosh	OK	S. Canadian R.	29 Jun 29	?	15351
Muskogee	OK	Ark. R., Hwy 104, 2 mi E of Haskell	23 Apr 81	1	43175
Okfuskee	OK	N. Canadian R., T1N, R12E, S27	25 Jul 62	500	35227
Osage	OK	Miller Crk., T21N, R9E, S30	06 Aug 60	4	38989
Osage	OK	Mudder Crk., 5.5 mi N of damsite	22 Jun 60	5	38623
Osage	OK	Walnut Crk.	23 Jun 60	22	39063
Osage	OK	2nd C, E. of Salt Crk.	15 Jun 60	2	39056
Pawnee	OK	Cimarron R., T2oN, R10E, S31	09 Aug 60	33	39020
Pawnee	OK	T20N, R9E, S22; 1 mi S of Hwy 64	15 Jun 60	201	38582
Pawnee	OK	Arkansas R., Turkey Island	07 Jul 34	?	15335
Payne	OK	Cimarron R., T19N, R7E, S27	07 Feb 60	2	38949
Payne	OK	Cimarron R., Ripley bridge on Hwy 33	?	?	15342
Pittsburg	OK	Gaines Crk., 4 mi N Hartshorne	13 Aug 62	2	36027
Pittsburg	OK	Small Crk., at S. Canadian R.	20 Jun 62	1	34594
Pittsburg	OK	Pools; S. Canadian R.	20 Jun 62	13	34617
Pittsburg	OK	Longtown Crk., at mouth	20 Jun 62	9	34663
Pontotoc	OK	S Canadian R., Rt 99 bridge S Konowa	14 Oct 78	71	41752
Roger Mills	OK	S Canadian R.; 6 mi NW Durham	- - 26	1	6196
Texas	OK	Palo Duro Crk; on Hwy 3	04 Jun 57	9	26365
Texas	OK	Beaver R., Hwy 64, T3N, R15E, S13	19 Jun 63	48	32301
Texas	OK	Palo Duro Crk., T1N, R18E, S23	19 Jun 63	25	32282
Texas	OK	Palo Duro Crk., T1N, R18E, S23	19 Jun 63	81	32288
Texas	OK	Coldwater Crk., T1N, R16E, S16&17	20 Jun 63	44	32339

Texas	OK	Beaver R., T2N, R18E, S2	19 Jun 63	73	32295
Texas	OK	Beaver R., T3N, R17E, S27	19 Jun 63	152	32277
Texas	OK	Coldwater Crk., Hwy 3; 2N, 17E, S15	19 Jun 63	51	32266
Texas	OK	Beaver R., T3N, R13E, S23	20 Jun 63	45	32345
Texas	OK	Coldwater Crk., 8 mi SE of Guymon	01 Jul 26	215	6205
Tulsa	OK	Arkansas R at Keystone	03 Aug 60	5	39035
Wagoner	OK	Verdigris R.; T16N, R19E, S19	02 Mar 57	4	28724
Woods	OK	Cimarron R.	01 Jul 30	?	15350
Woodward	OK	Wolf Crk., Rt. 270 bridge	02 May 53	3	29834
Woodward	OK	Wolf Crk., Rt. 270 bridge	02 May 53	1	28835
Woodward	OK	Wolf Crk., below Ft Supply dam	24 Jun 63	9	32333
Woodward	OK	Bent Crk., T20N, R17W, S22	05 May 62	1	36660
Woodward	OK	N. Canadian R.	13 Jul 28	?	15357

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Alfalfa	OK	Medicine Lodge R. near Cherokee	26 Apr 41	5	2127
Barber	KS	Medicine Lodge R., T33S, R11W, S20/21	12 Jun 58	91	3925
Barber	KS	Medicine Lodge River, at Sun City	18 Aug 57	34	3901
Barber	KS	Elm Crk., 5 mi S Rt 160; 32S, 12W, S12	21 Jul 51	1	1800
Barton	KS	Arkansas R., 19S, 12W, S32	11 Aug 52	11	2662
Beaver	OK	N. Canadian R., 4 mi S of Floris	03 Apr 60	83	6888
Beaver	OK	Beaver R., on US Rt 83	22 Apr 72	44	14712
Beaver	OK	N Canadian R., 4 mi S of Gate	04 Sep 51	37	2016
Caddo	OK	Canadian R. trib; S of Hydro on Rt 58	22 Apr 64	60	8039
Clark	KS	Cimarron R., 8 mi S Sitka	03 Apr 62	20	8269
Clark	KS	Cimarron R., 34S, 21W, S20	?	4	20664
Cleveland	OK	S Canadian R; Newcastle on Rts 62/277	15 Apr 52	89	2330
Comanche	KS	Mule Crk., 16 mi E of Coldwater	18 Jul 64	24	8575
Comanche	KS	Mule Crk., 32S, 16W, S10	29 Aug 60	9	6423
Cowley	KS	Arkansas R., 33S, 3E, S22	27 Aug 56	36	3654
Cowley	KS	Arkansas R., 34S, 3E, S22	25 Aug 56	52	3671
Finney	KS	Arkansas R., S of Holcomb	11 Aug 52	41	2651
Garvin	OK	Wildhorse Crk., 1N, 1E	25 Apr 68	1	12966
Grant	KS	Cimarron R., 12 mi S Ulysses on Rt 270	08 Apr 55	39	3455
Hemphill	TX	Canadian R. at Canadian	?	125	3410
Kingman	KS	S Fork Ninnescah R., 28S, 10W, S1	12 Apr 58	2	4608
Kingman	KS	S Fork Ninnescah R., SW Cheney; 28S,5W	22 Jul 64	27	8531
Meade	KS	Crooked Crk., 8 mi S & 2.5 mi W Meade	17 Jul 64	27	8564
Meade	KS	Cimarron R., KS Rt 23 bridge S Meade	17 Jul 64	174	8572
Meade	KS	Crooked Crk., on Rt 98; 33S, 28W, S20	29 Aug 60	6	6427
Meade	KS	Cimarron R., 35S, 29W, S8	?	38	20681
Meade	KS	Crooked Crk., 33S, 28W, S9	14 Jun 58	30	3953
Meade	KS	Cimarron R., S of KS Rt 23 bridge	?	12	21696
Morton	KS	Cimarron R., Pt-of-Rocks; 34S, 42W, S7	02 Apr 62	16	8474
Morton	KS	Cimarron R., 34S, 43W, S21	?	1	21719
Oldham	TX	Canadian R., 11 mi S of Channing	23 Feb 57	50	6745
Potter	TX	Canadian R., N of Amarillo	?	127	3245
Roberts	TX	Canadian R., at TX Rt 70	22 Apr 72	213	14703
Sedgwick	KS	Arkansas R., 27S, 1E, S18	01 Mar 52	4	2029
Sedgwick	KS	Arkansas R., 0.5 mi N Rt 54, Wichita	26 Jan 52	2	2007
Seward	KS	Cimarron R., 5 mi SW Kismet on Rt 54	06 Apr 55	2	3451
Seward	KS	Cimarron R., 32S, 33W, S8/17	14 Jun 58	124	3959
Seward	KS	Cimarron R., 4.5 mi SW Kismet	08 Apr 56	4	3566
Sumner	KS	Arkansas R., at Oxford, N of Rt 160	02 Apr 67	281	12192
Sumner	KS	Arkansas R., 31S, 2E, S36	06 Apr 55	484	3472
Sumner	KS	Ninnescah R., on KS turnpike, S Wichita	26 Jun 64	6	8283
Texas	OK	N Canadian R.; US Rt 54, 2 mi SW Optima	12 Sep 62	50	8336
Texas	OK	Beaver R., 3.5 mi SW Optima	01 Apr 56	151	3564

COLLECTION OF VERTEBRATES, OKLAHOMA STATE UNIVERSITY (OSUS)

Alfalfa	OK	Medicine Lodge R., NE Cherokee	26 Apr 41	42	222
Alfalfa	OK	Salt Fork, N of Cherokee	26 Apr 41	117	355
Chaves	NM	Pecos R., Lake Arthur Falls;15S,26E,S26	20 Aug 87	25	14328
Cimarron	OK	Palo Duro Crk.	29 May 49	15	4125
Harper	OK	Beaver R., N of May	17 Jun 47	223	577

Harper	OK	Beaver R., at bridge N of Laverne	17 Jun 47	40	1715
Harper	OK	Beaver R., N of May	17 May 47	194	12510
Kay	OK	Salt Fork Arkansas, 8 mi S Ponca City	26 Feb 61	171	11809
Kay	OK	Chickaskia R., 1 mi N, 1 mi E Tonkawa	16 Mar 40	74	48
Logan	OK	Skeleton Crk., N of Guthrie	24 Jun 39	7	1456
Noble	OK	Skeleton Crk.	29 Mar 47	297	363
Okmulgee	OK	Deep Fork R., 1 mi W Okmulgee	25 Mar 32	4	1965
Pawnee	OK	Red Rock Crk., near mouth	18 Feb 50	20	4061
Payne	OK	Cimarron R., SE of Perkins	09 Apr 32	2	1967
Payne	OK	Wildhorse Crk., Hastings farm	09 Apr 32	6	1966
Payne	OK	Small Crk., 1 mi S, 4 mi E Perkins	09 Apr 32	3	1968
Payne	OK	Wildhorse Crk., W of Perkins	09 Apr 32	3	1421
Payne	OK	Cimarron R., mouth of Stillwater Crk.	08 Apr 65	144	6075
Payne	OK	Headquarters Crk.;1 mi S,4 mi E Perkins	09 Apr 32	4	1414
Payne	OK	Cimarron R., SE Perkins	09 Apr 32	5	407
Payne	OK	Cimarron R., at S end of Perkins bridge	01 Jul 46	188	?40
Payne	OK	Cimarron R., 13 mi S of Stillwater	10 Feb 40	35	1462
Payne	OK	Mouth of Stillwater Crk.	07 Mar 74	?	7623
Sequoyah	OK	Arkansas R., locksite 14 near Muldrow	15 Nov 63	1	14341
Sequoyah	OK	Arkansas R., 6 mi S of Muldrow	05 May 50	1	4621
Texas	OK	N of Guymon	29 May 49	312	4129
Woodward	OK	Wolf Crk., below Ft. Supply dam	27 May 49	1	4081
Woodward	OK	N Canadian R., at Woodward	02 May 53	7	13082

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Logan	AR	Arkansas R., near mouth of Piney Crk	23 Jul 39	7	128394
-	KS	Arkansas River about 2 miles E of Kinsley	23 Sep 26	9	94947
-	KS	?	06 Sep 26	18	122254
-	KS	Medicine Lodge R., 5 mi. NW of Medicine Lodge	12 Nov 38	2	126798
-	KS	Mulberry Crk, below 1st dam, 0.5 mi NW of Ford	29 Apr 39	6	126811
-	KS	Medicine Lodge River, 0.75 mi S of Lake City	12 Nov 38	4	126817
Barber	KS	Medicine Lodge River, NE of Kiowa	11 Jul 40	64	144966
Barber	KS	Medicine Lodge River, 2 mi S of Medicine Lodge	11 Jul 40	35	144969
Barber	KS	Medicine Lodge River, 5 mi SE of Belvedere	12 Jul 40	8	144977
Finney	KS	Arkansas R, SW Garden City, 0.5 mi above Hwy 83	25 Jul 50	11	160433
Ford	KS	Arkansas River near Dodge City	15 Jul 40	9	145000
Ford	KS	Mouth of Mulberry Creek near Ford	15 Jul 40	11	145007
Gray	KS	Arkansas R., S of Charleston	14 Jul 40	1	144990
Hamilton	KS	Arkansas R., about 0.5 mi. due S of Syracuse	25 Jul 50	1	160442
Meade	KS	Crooked Crk, at Borchers Pasture, T33S R28W S21	26 Jun 52	13	176839
Meade	KS	Crooked Crk, at Borchers Pasture	01 Jul 52	1	176848
Meade	KS	Crooked Crk, @ crossing 3 mi S Borcher Quarry	04 Jul 41	13	134642
Meade	KS	Crooked Crk, 8 mi S & 2.25 mi W of Meade	24 Jul 50	4	160420
Reno	KS	Arkansas R., at Hutchinson, just W of Carey Prk	07 Aug 39	6	128867
Seward	KS	Cimarron R; XI Ranch, SE Arklon, T34S R31W S25	19 Aug 51	77	161990
Sumner	KS	Side pools of Arkansas R, 1 mi N to NE Oxford	15 Jun 39	145	127635
-	OK	Cimarron R, 9 mi S, 2 mi W of Stillwater	14 Mar 36	402	113357
-	OK	Salt Fork of Arkansas R, S of Ponca City	18 Jun 32	12	110909
-	OK	Cimarron R, near Stillwater	-	203	113335
-	OK	Arkansas R, near Ralston	11 Jul 36	177	113371
-	OK	Cimarron R, near Ripley	-	11	113380
-	OK	S Canadian R, 4.5 mi SW of Norman	30 Oct 20	50	73019
-	OK	Canadian R, near Norman	-	4	73042
-	OK	Little R, 10 mi E of Norman	30 May 26	6	80494
Alfalfa	OK	Salt Fork of Ark. R; 7 mi E & 2 mi N Ingersoll	11 Jul 26	7	80464
Alfalfa	OK	Salt Fork of Ark. R; 7 mi E & 2 mi N Ingersoll	11 Jul 26	1182	80465
Alfalfa	OK	Pond, 3.5 mi E of Cherokee, just S of 5th St Rd	13 Jun 30	122	109377
Alfalfa	OK	Salt Fork of Ark. R., 9 mi E of Cherokee	20 Jun 30	240	109378
Alfalfa	OK	Salt Fork of Ark. R., 5 mi N of Cherokee	21 Jun 30	176	109379
Caddo	OK	Deer Crk, US 66 betw. Bridgeport & Weatherford	29 Sep 40	6	133128
Cimarron	OK	Cimarron R., main channel , 3 mi NW Kenton	02 Jul 26	1	80439
Cimarron	OK	Cimarron R., main channel, 3 mi NW of Kenton	02 Jul 26	94	80440
Cimarron	OK	West Carrizo Crk, 3.5 mi N of Kenton	07 Jul 26	16	80460
Cleveland	OK	Canadian R, S of Norman	- - 34	63	110897
Dewey	OK	S Canadian R, 4 mi SW of Taloga	11 Jul 28	209	108835
Dewey	OK	S Canadian R, 0.75 mi NW of Taloga	11 Jul 28	578	108836
Harper	OK	Sleeping Bear Crk, 20 mi SE of Buffalo	11 Jul 26	1	80475
Kay	OK	Salt Fork of Ark. R., S of Ponca City	24 Aug 39	314	127204

Kay	OK	Chikaskia R, 1 mi N & 1 mi E of Tonkawa	16 Mar 40	1038	210640
Kay	OK	Salt Fork of Ark. R., 3 mi S of Tonkawa	16 Mar 40	41	212704
Kay	OK	Salt Fork R., S of Tonkawa	17 Apr 40	96	193726
LeFlore	OK	Arkansas R, 5.5 mi SW of Fort Smith	04 Jul 27	4	80930
Logan	OK	Cimarron R, below mouth of Skeleton Crk	04 Aug 39	65	127186
Logan	OK	Cimarron R., 1 mi N of Coyle	25 Jul 29	705	108947
Major	OK	Eagle Chief Crk	15 Jun 40	1	193758
Major	OK	Cimarron R, 3 mi S of Cleo Springs	18 Jul 28	1068	108839
Major	OK	Eagle Chief Crk, 0.25 mi NW of Cleo Springs	18 Jul 28	7	108840
Major	OK	Eagle Chief Crk, Cleo Springs	27 Jun 30	45	109380
Major	OK	Cimarron R., 3 mi S of Cleo Springs	28 Jun 30	736	109381
McClain	OK	S Canadian R, at Purcell	28 Jul 32	225	110012
McClain	OK	Walnut Crk, 0.5 mi S of Purcell	28 Jul 32	39	110013
McIntosh	OK	S Canadian R, 3 mi S of Eufaula	29 Jun 29	9	108946
Noble	OK	Salt Fork Ark. R., 5 mi N of Marland	24 Aug 39	472	127279
Okmulgee	OK	Deep Fork R., 1 mi W of Okmulgee	25 Mar 32	26	108342
Pawnee	OK	Turkey Island, Arkansas River	07 Jul 34	162	110882
Payne	OK	Cimarron R, 4 mi E of Ripley	12 Nov 39	1	127160
Payne	OK	Cimarron R, at Ripley bridge	26 Apr 35	229	113348
Payne	OK	Cimarron R, Ripley bridge	14 Jul 35	106	108433
Payne	OK	Small creek, 1 mi S, 4 mi E of Perkins	09 Apr 32	16	108302
Payne	OK	Small creek, 1 mi S, 4 mi E of Perkins	09 Apr 32	1	108350
Payne	OK	Cimarron R, at the mouth of Stillwater Crk	04 Feb 39	445	210556
Payne	OK	Cimarron R, 13 mi S of Stillwater	10 Feb 40	1110	210638
Payne	OK	Cimarron R, 1 mi W of Perkins bridge	- - 41	480	193732
Payne	OK	Mouth of Stillwater Crk, near bridge	05 Nov 38	248	122340
Payne	OK	Stillwater Crk, 0.25 mi S of Mehan	05 Nov 38	3	122349
Payne	OK	Stillwater Crk, W of Mehan	12 Nov 38	9	122361
Payne	OK	Cimarron R., near Perkins	28 Apr 34	107	110941
Payne	OK	Ripley bridge, Cimarron R. on Hwy 33	- Apr 34	1179	110891
Payne	OK	Creek, 1 mi S and 4 mi E of Perkins	01 Apr 37	8	119949
Payne	OK	Cimarron River	18 Mar 37	63	119958
Payne	OK	Cimarron River	10 Apr 37	69	119961
Payne	OK	Cimarron R trib, 9 mi S & 1 mi W of Stillwater	10 Apr 37	70	119969
Roger Mills	OK	S Fork Canadian R, 6 mi NW of Durham	01 Apr 37	8	119949
Payne	OK	Cimarron River	18 Mar 37	63	119958
Payne	OK	Cimarron River	10 Apr 37	69	119961
Payne	OK	Cimarron R trib, 9 mi S & 1 mi W of Stillwater	10 Apr 37	70	119969
Roger Mills	OK	S Fork Canadian R, 6 mi NW of Durham	_ Jun 26	1	80416
Texas	OK	Coldwater Crk, 8 mi SE of Guymon	01 Jul 26	101	80426
Tulsa	OK	Arkansas R., 1 mi up from Sand Sprgs bridge	28 Aug 36	32	116729
Woods	OK	Main Crk of Cimarron R, 10 mi NW of Togo	16 Jul 28	30	108838
Woods	OK	Cimarron R, 2 mi W and 1 mi S of Waynoka	01 Jul 28	35	109382
Woodward	OK	N Canadian R, 5 mi E & 1 mi N of Woodward	13 Jul 28	2122	108837

APPENDIX B

OCCURRENCE OF ARKANSAS RIVER SHINER IN J. PIGG'S COLLECTIONS FROM 13 LOCALITIES

Occurrence of Arkansas River shiner in collections made at 13 sites in the Arkansas River drainage from 1977 to 1990. Dates of collections are subtended by the number of specimens of Notropis girardi collected. Parentheses indicate specimens reported by J. Pigg (unpublished data, Oklahoma Department of Health) but not located. Zeros indicate no specimens were found and none reported for that collection. na = data was not available.

Beaver (North Canadian) River, south of Turpin, Beaver County. T3N R21E S6.

	Number of collections per year		
	1	2	3
1982	6/14/82 25		
1983	6/07/83 8	7/18/83 207	
1984	6/05/84 0	7/23/84 0	
1985	6/02/85 0	6/04/85 1	7/15/85 0
1986	6/02/86 0	7/12/86 (1)	
1987	5/22/87 0	7/01/87 (3)	
1988	5/24/88 0	7/17/88 0	
1989	5/22/89 0	7/24/89 0	
1990	na	7/17/90 4	

North Canadian River at the northeast corner of Woodward, Woodward County. T23N R20W S25

	Number of collections per year		
	1	2	3
1978	8/02/78 0		
1979	6/14/79 0	7/13/79 0	
1980	6/03/80 0	7/15/80 13	
1981	6/15/81 1 +(4)	7/15/81 (2)	9/20/81 (1)
1982	6/14/82 (1)	7/14/82 0	9/27/82 0
1983	6/06/83 0	7/18/83 0	10/02/83 3
1984	6/04/84 0	7/23/84 0	9/30/84 0
1985	6/04/85 0	7/15/85 0	10/06/85 0
1986	6/02/86 0	7/14/86 0	
1987	5/02/87 0	7/01/87 0	
1988	5/23/88 0	7/12/88 0	9/11/88 0
1989	6/05/89 0	7/24/89 0	10/15/89 0
1990	na	na	na

Salt Fork of the Arkansas River north of Jet below Great Salt Plains Reservoir, Alfalfa County. T26N R9W S11

	Number of collections per year		
	1	2	3
1976	6/03/76 0		
1977	6/02/77 3	7/07/77 27	
1978	5/26/78 74	6/22/78 0	8/02/78 8 +(2)
1979	6/05/79 (2)	7/02/79 5	
1980	6/03/80 1	7/16/80 3	10/11/80 24
1981	7/02/81 0	7/16/81 (9)	9/20/81 5
1982	6/15/82 0	7/09/82 10 + (9)	9/27/82 3
1983	6/07/83 1	7/19/83 1	10/02/83 3
1984	6/06/84 0	7/24/84 0	9/30/84 0
1985	6/06/85 0	7/18/85 0	10/06/85 0
1986	6/03/86 0	7/14/86 0	9/20/86 1
1987	5/02/87 0	6/30/87 1	
1988	7/14/88 0	5/24/88 0	9/11/88 0
1989	5/24/89 0	7/26/89 0	10/15/89 0
1990	na	na	na

Salt Fork of the Arkansas River north of Nash, Grant County, Oklahoma. T26N R8W S27

	Number of collections per year		
	1	2	3
1979	6/05/79 0	7/02/79 0	10/06/79 8
1980	6/04/80 0	7/16/80 0	10/11/80 4
1981	7/02/81 0	7/16/81 (62)	9/20/81 (43)
1982	8/02/82 2	9/11/82 0	9/27/82 0
1983	6/07/83 0	7/19/83 0	10/02/83 0
1984	6/06/84 0	7/24/84 0	9/30/84 2
1985	6/06/85 0	7/18/85 0	10/06/85 0
1986	6/03/86 0	7/15/86 1	9/20/86 0
1987	5/02/87 0	6/30/87 0	
1988	5/24/88 0	7/14/88 0	9/11/88 0
1989	5/24/89 0	7/26/89 0	10/15/89 0
1990	na	na	na

Cimarron River South of Englewood Kansas, Harper County, Oklahoma.
T29N R26W S24

	Number of collections per year		
	1	2	3
1981	7/16/81 0		
1982	6/15/82 3		
1983	6/07/83 22	7/19/83 8	
1984	6/06/84 25		
1985	6/05/85 1		
1986	6/03/86 0		
1987	5/23/87 0	7/01/87 0	
1988	5/24/88 1	7/13/88 0	
1989	5/24/89 0	7/26/89 0	
1990	na	na	

Cimarron River south of Cleo Springs, Major County, Oklahoma.
T22N R12W S23

	Number of collections per year		
	1	2	3
1979	6/14/79 4	7/13/79 84	
1980	6/04/80 2	7/16/80 (11)	
1981	6/15/81 47	7/21/81 4 +(3)	
1982	6/17/82 3+(2)	7/14/82 0	
1983	6/08/83 5	8/09/83 31	
1984	6/06/84 13	6/23/84 46	7/24/84 27
1985	6/28/85 2	7/17/85 5	
1986	6/03/86 1	7/15/86 0	
1987	5/27/87 0	6/30/87 0	
1988	5/24/88 0	7/14/88 0	
1989	6/05/89 0	7/26/89 0	
1990	na	na	

Cimarron River near Dover, Kingfisher County, Oklahoma.
T17N R7W S14

	Number of collections per year		
	1	2	3
1979	3/20/79 101 +(1414)	6/14/79 15	7/13/79 38
1980	6/04/80 11	7/14/80 3	
1981	7/02/81 0	7/21/81 9	
1982	6/17/82 (1)	7/14/82 1	
1983	6/08/83 27	8/08/83 0	
1984	6/23/84 0	8/14/84 0	
1985	6/28/85 1	7/18/85 1	
1986	5/30/86 0	8/05/86 0	
1987	6/10/87 0	6/30/87 0	
1988	7/14/88 0	5/19/88 0	
1989	5/20/89 0	7/18/89 0	
1990	na	na	

Cimarron River south of Perkins, Payne County, Oklahoma. T17N R3E S7.

	Number of collections per year		
	1	2	3
1976	6/04/76 (25)		
1977	6/01/77 18	7/06/77 81 +(234)	
1978	5/24/78 (29)	6/30/78 12	
1979	5/29/79 113 +(6)	6/26/79 13 +(11)	10/21/79 2 +(23)
1980	7/03/80 (2)	8/01/80 19	11/02/80 7
1981	5/25/81 2 +(2)	7/24/81 63 +(132)	10/04/81 5
1982	6/18/82 0	8/09/82 5	10/03/82 (1)
1983	6/20/83 0	8/10/83 4	10/08/83 6
1984	5/21/84 (1)	8/13/84 3	10/14/84 0
1985	5/22/85 0	7/19/85 0	9/14/85 (1)
1986	5/27/86 0	7/16/86 0	10/17/86 0
1987	8/14/87 0	9/05/87 0	10/17/87 0
1988	5/13/88 0	8/09/88 0	
1989	5/26/89 0	8/02/89 0	10/01/89 0
1990	na	na	na

Arkansas River at Ralston, Pawnee/Osage County, Oklahoma. T23N R5E S1.

	Number of collections per year			
	1	2	3	4
1977	7/06/77 (3)			
1978	6/13/78 (13)	7/11/78 0		
1979	6/07/79 0	7/02/79 0	10/13/79 0	
1980	4/05/80 1 +(1)	6/11/80 0	7/19/80 0	10/11/80 0
1981	5/29/81 0	7/28/81 0	10/04/81 0	
1982	7/09/82 3	7/30/82 0	10/03/82 0	
1983	6/21/83 0	8/03/83 (2)	10/08/83 0	
1984	7/02/84 0	8/26/84 0	10/14/84 0	
1985	6/11/85 0	8/09/85 0	9/14/85 0	
1986	6/04/86 (1)	9/06/86 0		
1987	6/17/87 0	8/14/87 0	10/17/87 0	
1988	6/15/88 0	7/21/88 0	10/02/88 0	
1989	6/06/89 0	8/02/89 0	10/01/89 0	
1990	na	8/13/90 0	10/13/90 0	

South Canadian River, near Bridgeport, Blaine County, Oklahoma. T13N, R11W, S28.

	Number of collections per year			
	1	2	3	4
1976	6/04/76 (0)			
1977	6/11/77 (204)	7/15/77 (653)		
1978	5/23/78 (2503)	6/21/78 (1306)		
1979	5/23/79 (6)	6/25/79 (1635)		
1980	4/22/80 (555)	5/23/80 (466)	7/14/80 (686)	11/01/80 (785)
1981	5/19/81 (253)	7/20/81 (217)	9/19/81 (103)	
1982	6/10/82 (328)	7/12/82 (224)	9/26/82 (304)	
1983	5/27/83 (385)	7/11/83 (1080)	10/01/83 (282)	
1984	5/13/84 (655)	7/05/84 (404)	9/23/84 (173)	
1985	5/19/85 (62)	7/11/85 (634)	9/22/85 (93)	
1986	5/10/86 (354)	7/02/86 (40)	8/13/86 (52)	
1987	5/09/87 (101)	7/09/87 (35)	9/25/87 (112)	
1988	7/01/88 (55)	10/24/88 (159)		

South Canadian River, north of Calvin, Hughes County, Oklahoma.
T6N, R10E, S22.

	Number of collections per year			
	1	2	3	4
1977	6/07/77 (0)	7/12/77 (1408)		
1978	5/25/78 (0)	6/23/78 (0)		
1979	6/04/79 (205)	6/29/79 (127)	10/28/79 (576)	
1980	6/20/80 (535)	7/29/80 (1191)	10/26/80 (125)	
1981	6/17/81 (0)	7/23/81 (499)	10/11/81 (20)	
1982	7/01/82 (0)	7/15/82 (1073)	10/24/82 (145)	
1983	6/22/83 (1139)	7/25/83 (4773)	10/16/83 (842)	
1984	6/08/84 (29)	7/18/84 (1331)	9/16/84 (285)	
1985	6/07/85 (7211)	10/13/85 (91)		
1986	5/31/86 (42)	8/29/86 (91)		
1987	6/09/87 (761)	7/11/87 (6551)	10/10/87 (238)	
1988	6/28/88 (315)			

Arkansas River at Sand Springs City Park, Tulsa County, Oklahoma.
T19N R11W S14.

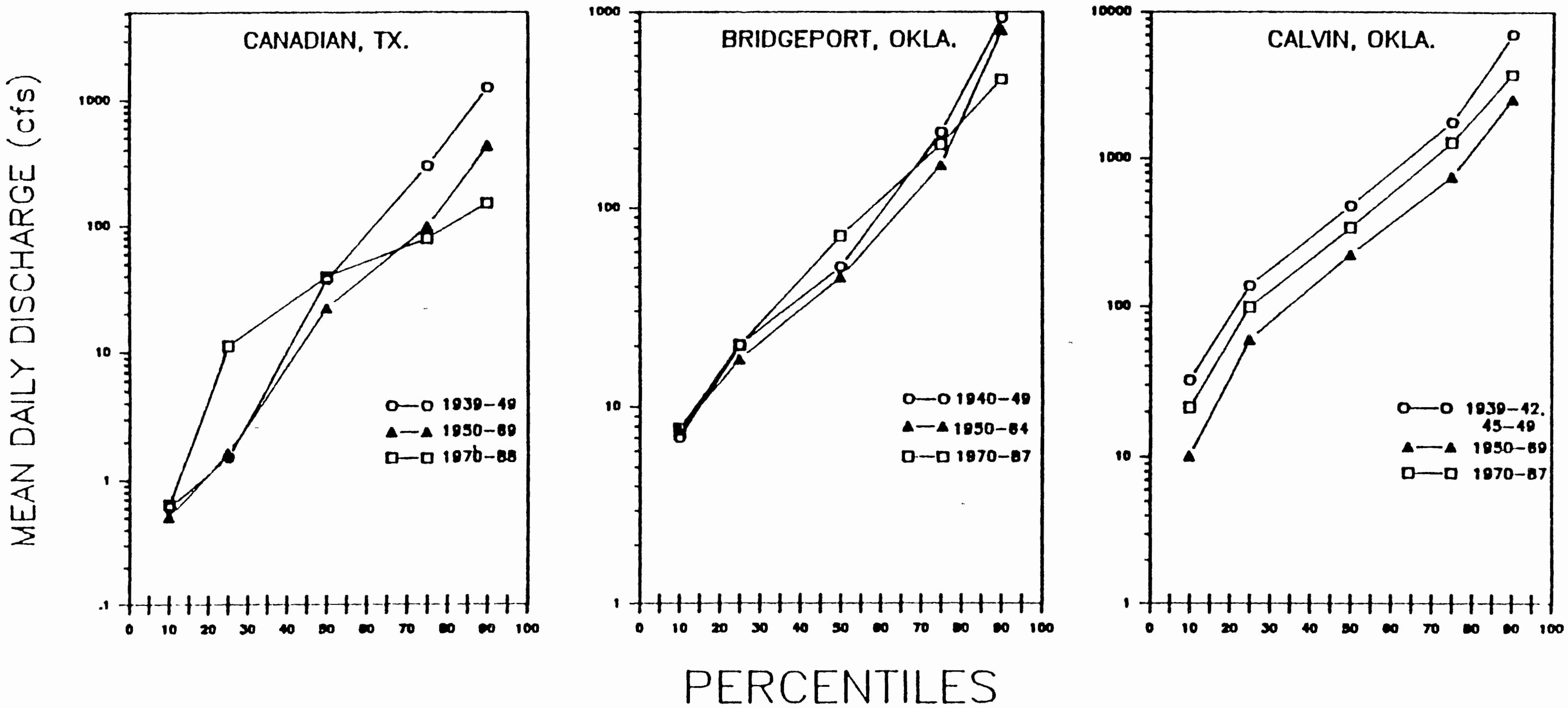
	Number of collections per year			
	1	2	3	4
1977	6/03/77 (1)	7/08/77 0		
1978	6/14/78 0	7/12/78 0		
1979	6/15/79 0	7/12/79 0	10/13/79 0	
1980	5/13/80 0	6/16/80 0	7/22/80 0	11/02/80 0
1981	7/01/81 0	7/24/81 0	10/25/81 0	
1982	7/08/82 (5)	7/28/82 0	10/17/82 0	
1983	7/05/83 0	8/21/83 0	10/08/83 0	
1984	6/27/84 0	8/18/84 0	10/17/84 0	
1985	6/17/85 0	7/24/85 0	9/15/85 0	
1986	7/30/86 0	8/29/86 0		
1987	6/19/87 0	8/29/87 0		
1988	6/02/88 0	8/16/88 0		
1989	6/07/89 0	8/03/89 0	10/08/89 0	
1990	na	na	na	

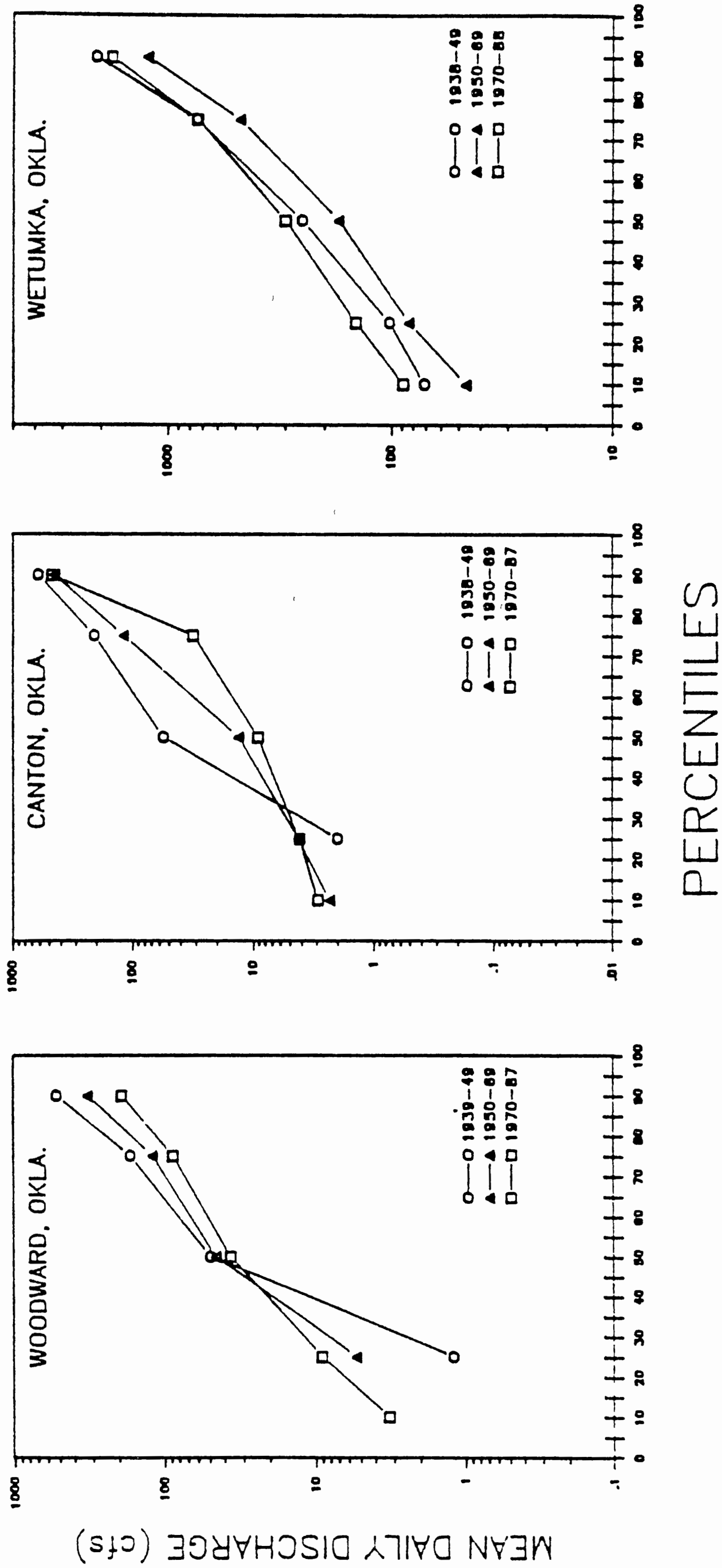
Arkansas River south of Sallisaw, Leflore County, Oklahoma. T10N R24E S9.

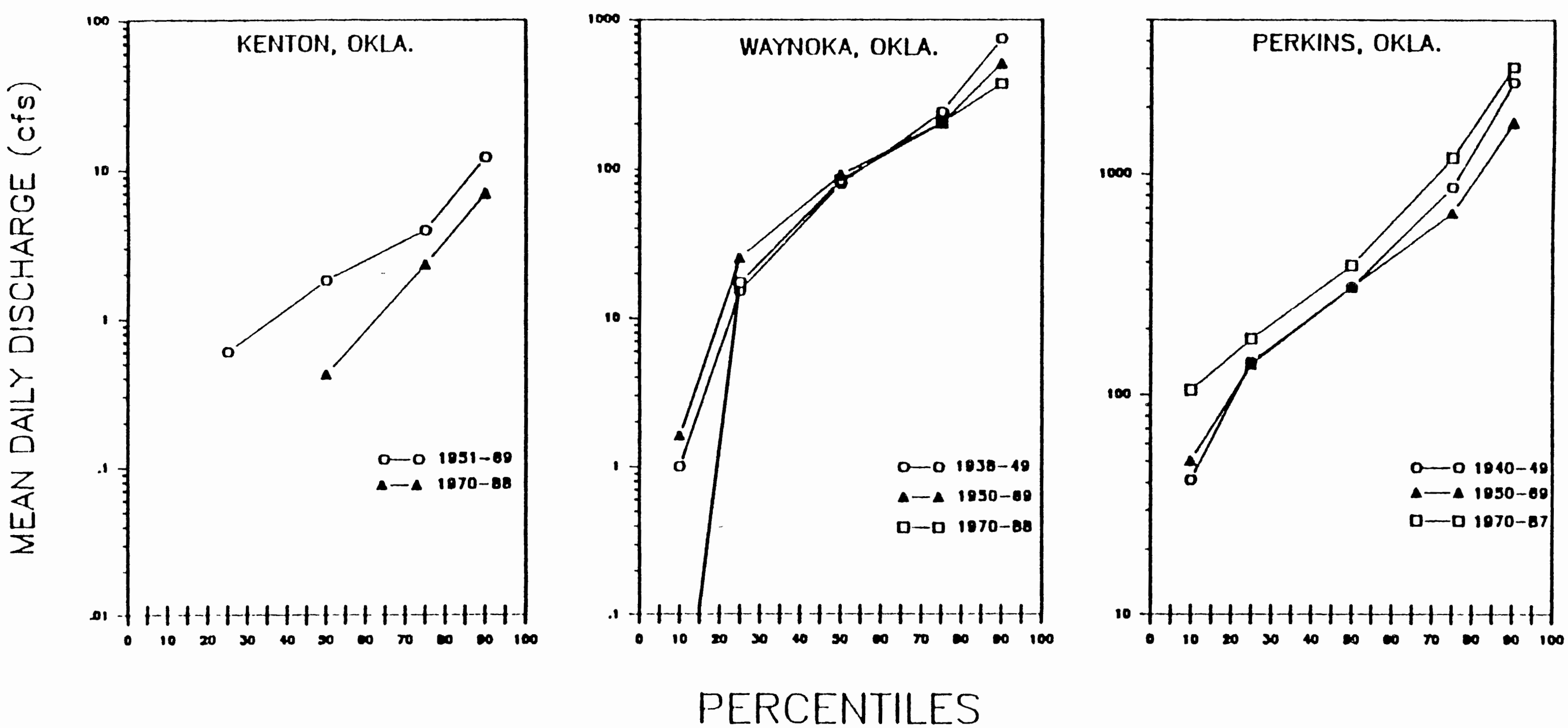
	Number of collections per year			
	1	2	3	4
1978	6/19/78 0	7/17/78 0		
1979	6/11/79 0	7/11/79 0		
1980	6/26/80 0	7/24/80 0		
1981	6/30/81 0	8/03/81 0	10/09/81 0	
1982	6/29/82 0	7/19/82 (5)		
1983	6/27/83 0	7/20/83 0		
1984	6/11/84 0	8/05/84 0		
1985	6/23/85 (1)	7/29/85 0		
1986	6/28/86 0	8/16/86 0		
1987	8/16/87 0			
1988	6/08/88 0	7/26/88 0		
1989	6/01/89 0	8/01/89 0		
1990	na	na		

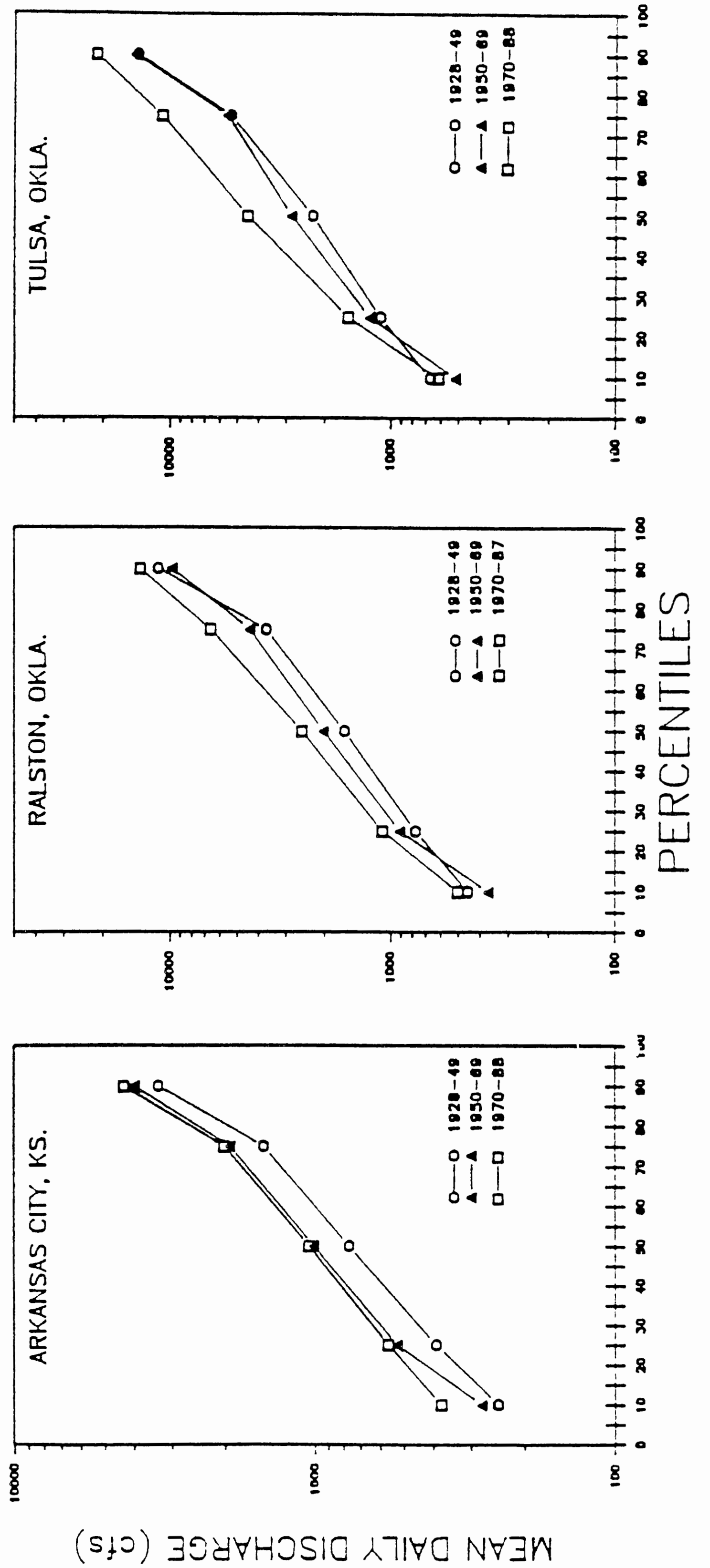
APPENDIX C

FLOW DURATION CURVES FOR 12 SITES IN
THE ARKANSAS RIVER DRAINAGE


CANADIAN, TX.
BRIDGEPORT, OKLA.
CALVIN, OKLA.
MEAN DAILY DISCHARGE (cfs)
PERCENTILES
1939-49
1950-69
1970-88
1940-49
1950-64
1970-87
1939-42, 45-49
1950-69
1970-87


WOODWARD, OKLA.
1939-49
1950-69
1970-87
CANTON, OKLA.
1938-49
1950-69
1970-87
WETUMKA, OKLA.
1938-49
1950-69
1970-88
PERCENTILES
MEAN DAILY DISCHARGE (cfs)


MEAN DAILY DISCHARGE (cfs)
KENTON, OKLA.
1951-69
1970-88
WAYNOKA, OKLA.
1938-49
1950-69
1970-88
PERKINS, OKLA.
1940-49
1950-69
1970-87
PERCENTILES


ARKANSAS CITY, KS.
O—O 1928-49
▲—▲ 1950-69
□—□ 1970-88
RALSTON, OKLA.
O—O 1928-49
▲—▲ 1950-69
□—□ 1970-87
TULSA, OKLA.
O—O 1928-49
▲—▲ 1950-69
□—□ 1970-88
10000
1000
100
0 10 20 30 40 50 60 70 80 90 100
PERCENTILES
MEAN DAILY DISCHARGE (cfs)

VITA

ROBERT D. LARSON JR.

Candidate for the Degree of

Master of Science

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