Aquatic Habitats and Fish Distribution in a Large Oklahoma River, the Cimarron, From 1976 to 1986

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Fishes of the Cimarron River, a large Oklahoma river, were sampled from 1976 to 1986 with seines and gill nets. Ten stations were established and a 200-meter area was sampled two or three times yearly. A total of 50 species and 347,902 specimens were used to compare the four major ecoregions and the ten sampling sites. The composition, abundance, seasonal and spatial distribution, and diversity of the fish populations were determined for each station. The ichthyofaunal data were used to correlate certain water quality parameters with spatial and temporal components of fish communities. Alterations of these community parameters were most pronounced in areas of elevated mineralization due to high levels of chlorides and sulfates. Overall fish abundance, species diversity, species counts, and species distribution at sites of elevated salinity were significantly affected. The changing patterns of the community characteristics during the ten-year period were summarized with special emphasis on their connection with certain chemical and physical changes in the river. A new fish community richness rating scale was utilized, and showed a distinct relationship in the spatial distribution and the ratings during this study. Most of the upper stations were rated as "poor" fish communities; the downstream stations were rated as "fair".

INTRODUCTION

The ichthyofauna of many major rivers in Oklahoma and Kansas, for example, Muddy Boggy River (1), Kiamichi River (2) and Brier Creek (3) in Oklahoma, and Smoky Hill River (4) and Arkansas and Cimarron Rivers (5) in Kansas, have received an intense but short-term study.

Long-term studies are essential if one is to understand fluctuations of populations and evaluate effects of natural and human disturbances. Few such studies have been conducted on fish communities of large Oklahoma rivers. Soon after the establishment of the Oklahoma State Department of Health (OSDH) Biotrend Monitoring Program in 1976, ten study sites along the Cimarron River in Oklahoma were designated. Collections were taken by staff members two or three times a year by seining and gill netting to delineate temporal and spatial components of the fish populations at these selected sites in the river basin.

The present paper describes the structure of and changes in fish communities sampled during 171 collection trips to ten sites on the Cimarron River from 1976 to 1986 in order to expand the knowledge of fishes in Oklahoma rivers and thus the Great Plains.

DESCRIPTION OF THE CIMARRON RIVER

The river has a total drainage area of 30,283 km², presumably with a long and narrow basin, as it transverses the 1,117 km from its source to mouth. The Cimarron River originates in northeastern New Mexico near Raton and enters Oklahoma at river kilometer 955 west of Kenton in Cimarron County. It flows there for 67 km and enters the extreme southeastern corner of Colorado and southwestern corner of Kansas. It returns to Oklahoma at a point north of Mocane in the northwest corner of Beaver County, then flows eastward to where it exits the state again from the northwest corner of Harper County. The river then reenters the state for the third and final time between Harper and Woods Counties at a point 24 km northeast of Buffalo. The river continues southeast through Woods, Woodward, Major, and Kingfisher Counties before it swings eastward through Logan and Payne Counties to its confluence with the main stream of the Arkansas River near the former town site of Mannford, which is now inundated by Keystone Lake.

MAJOR ECOREGIONS OF THE CIMARRON RIVER

The Cimarron River as it flows across Oklahoma passes through four major ecoregions of the state (6): the High Plains (headwaters, upper section), including Sites 1 and 2 in Cimarron County; the Western Plains (intermittent area, upper middle section), including Sites 3 and 4 in Harper, Woods, and Beaver Counties; the Central Reddish Prairie (middle river, lower middle section), which includes Sites 5, 6, and 7 in Major and Kingfisher Counties; and the Cross Timbers (downstream, lower section), including Sites 8, 9, and 10 in Logan and Payne Counties.

DESCRIPTION OF RIVER IN THE FOUR MAJOR ECOREGIONS

The High Plains Ecoregion in the Black Mesa area is well defined by several tributaries that have dissected the plateau. These tributaries slope sharply toward the main stream, have steep banks, and are deep. They are ephemeral and generally dry except during and after heavy rains. However, the three branches of Carrizozo Creek (North, South, and East) contain clear, deep, permanent pools filled with extensive growths of aquatic vegetation (coontail, filamentous green algae, and rushes) that provide good fish habitats. The westernmost section of the river is characterized by low rainfall (45 cm/year), a high evaporation rate, and very little runoff. Flows are seasonal and except during flash floods the flow is through a narrow stream bed with steep banks of fine silt to coarse gravel. In the upper ecoregion the river consists most of the year of isolated pools which are heavily impacted by the harsh climate and extensive utilization by cattle.

The Western (Rolling Red) Plains Ecoregion is somewhat smoother, with reclining sandy hills surrounding a broad, flat flood plain. In Beaver County there is rolling, dissected rangeland with steep breaks and sand-caked draws that drain the area. The Rolling Red Plains has a much drier climate, more wind, higher evaporation rate, and less vegetation cover than the Reddish Prairie. The tributaries, Crooked Creek and Horse Creek, contain clear permanent pools of water like those of Carrizozo Creek. However, the Cimarron at Site 3is usually dry during the late summer and fall. In the fall, Site 4 usually consisted of two or three very small, clear, shallow, isolated pools of water.

The major aquatic resources in the West Plains Ecoregion are Crooked, Horse, Keno, Day, Sand, and Moccasin Creeks. These streams are typically turbid during periods of high flow, and clear and shallow during the remainder of the year. Although Crooked Creek is smaller than the Cimarron River, it has a more dependable flow because it is spring fed. The major limiting factors for the aquatic habitats are drought and the shortage of permanent deep pools. Because the Cimarron River above its confluence with Crooked Creek sometimes ceases to flow, the deep pools in Crooked Creek support larger fish and serve as reservoirs for all aquatic life. As in the upper section, these areas are used by cattle for watering, which contributes to an increase in turbidity and disturbance of the aquatic ecosystem. The Cimarron River in the upper middle section is characterized by shifting channels and a wide flood plain, which narrows to 5 - 10 km near Site 3.

There are four major tributaries between the Kansas state line and Site 4 east of Buffalo. Day, Keno, and Lodge Pole Creeks have fairly good water quality with low chloride levels (52-700 mg/L). However, there is one major contributor of chlorides. A small unnamed left-bank tributary has chlorides as high as 150.5×10^3 mg/L. Between Sites 4 and 5, two major tributaries have high chloride levels, Elm (156×10^3 mg/L) and Buffalo (17×10^3 mg/L) Creeks. However, Sand and Moccasin Creeks have fairly good water.

The river is a wide meandering stream typical of the semiarid prairie as it passes through the Central Reddish Prairie Ecoregion. It is subject to severe water fluctuations due to seasonal heavy runoff and droughts. The climate in this area is highly variable, with long hot summers and moderate winters; annual rainfall is about 87 cm in the east and 70 cm in the west, which is within the range of subhumid climate.

There are two major tributaries. Eagle Chief Creek enters the river just south of Cleo Springs with relatively low salinity values, and is good enough in quality to improve the water of the river, with chloride values of 24-55 mg/L. The major chloride contributor is Salt Creek, which enters the river near Site 5 east of Okeene. A maximum chloride value of 193×10^3 mg/L has been recorded in Salt Creek.

As the river flows through the Cross Timbers Ecoregion (Sites 8 - 10), the climate is characterized by wide fluctuations in temperature. Summers are warm and winters are fairly mild, with short cold periods. Rainfall averages about 95 cm per year with a runoff of 15.2 cm per year, but there are annual differences, and severe droughts are common. The climatic conditions, along with both municipal and industrial waste water discharges, have helped to produce a more stable stream flow. There are two major tributaries. Cottonwood and Skeleton Creeks are permanent streams with poor water quality due to the influx of many point source discharges and non-point runoff waters. There is additional municipal waste water discharge by the city of Guthrie into the river above Site 8. In the past there have been fish kill incidents and inadvertent spills from oil-related activities.

AQUATIC HABITATS OF THE CIMARRON RIVER

The western section of the river has an aggraded channel, which is broad and uniformly sandy. Along its course in this section, it is a "losing" stream, unshaded, with high rate of evaporation and infiltration and a high dissolved-solid content (conductivity >2000 μmho). Habitats for fishes consist mostly of long shallow "runs" over shifting sand, interrupted by relatively small, shallow pools and backwaters along the banks and exposed sandbars. There is subsurface flow which emerges to sustain isolated pools and stretches of flowing water along its course. Much of the silt/sand substrata in these pools is covered by filamentous algae. Emergent aquatic vegetation (water buttercup, watercress, rushes, and cattails) are common along the stream margins.

The river flows reflect the severity of the climatic conditions (during three visits to Site 3 it was dry). Sites 1, 2, and 4 consisted of small isolated pools filled with extensive growths of filamentous algae during late summer visits.

The Cimarron River bed is fairly wide (110-250 m) from Sites 4 to 10 with a channel consisting of barren sand, devoid of aquatic vegetation. Vegetation is absent also in the clean sandy riverbed, although overhanging grasses and small patches of emergent vegetation cling to long sections of the river bank where it is undercut and algae are in isolated pools. The smooth channel is surrounded by moderately high banks (3-5 m) of loose sand and silt covered with scattered salt cedars and cottonwood trees. Below Site 3, the river channel widens, levels out and meanders more. This wide, open streambed is exposed to hot summer sun and hot winds that increase evaporation rates.

During the dry seasons, the river consists of many small, divided channels that meander over the open and uniform sandy bed. These consist of many small, narrow and shallow riffles of slow-moving, clear water. There are many small side channels and pools (maximum depth 0.6 m) covered with a film of organic matter, probably including living periphyton. There are shallow pools (0.3 - 1.0 m) at the ends of the long shallow riffles where the water drops off the edge of sandbars. During the dry periods the river consists of 75-85% shallow riffle habitat. There are usually a few deep pools (1.0 - 1.5 m) at bridge piers or log jams upstream from such piers. In most areas of the river one side is very shallow along the edge of an exposed sandbar. Along this edge, there are a number of small, isolated backwater pools with thick mats of green algae attached to the substrate. The other side of the river is usually deeper, with a raceway or fast-flowing deep channel next to the bank. This is where most of the fishes were concentrated during the summer months.

The substrate for Sites 1 and 2 consist of large cobble, coarse gravel, and fine silt. Substrate at Sites 3 through 5 is coarse unstable sand and a little gravel. At Sites 6 through 10 it consists of layers of fine reddish silt and mud laid down on a surface of fine, firm, sandy substrate. Pools and areas out of currents have a bottom layer of rich, reddish, soupy silt up to 0.3 m in depth and almost never contain any fish. However, in areas of strong flow, the substrate consists of firm fine sand.

Much of the silt/sand substrate is covered by filamentous algae and emergent vegetation at Sites 1 through 4. During low-flow periods or periods of no flow, the clear water pools were filled with large mats of filamentous green algae attached to almost any structures in the channel. During the dry periods, these isolated pools were filled with thick black layers of organic matter formed from decaying growths of algae and accumulated cattle waste.

The sandy banks of the Cimarron River have scattered vegetative cover from Sites 5 through 10. The banks are exposed both to water erosion at periods of high flow and wind erosion during the dry periods. Salt cedars make up most of the woody vegetation along the river. The entire river is very open, with little if any canopy.

Flooding has helped to keep the main river channel free from many obstructions that would hinder the flow of water. The major obstructions are usually man-made objects such as bridge piers. During this study, all sites except Site 2 had one or more sets of bridge piers crossing the channel. At Site 2, a low-water concrete dam with six openings crossed the channel, with small scour pools downstream from each opening. These pools contained the only water at this site during the dry season. Site 7, south of Dover, has three bridges crossing the sampling site.

At most bridge piers, accumulations of driftwood on the upstream side help form deep pools of water, as already noted. At Site 7, concrete from old bridges was left in the channel, and deep pools have been formed by hydraulic scour.

Pool habitats are very limited in the Cimarron River. At Sites 4 through 10, they comprise only 10 - 15 % of the available habitat. However, at Sites 1 and 2 they make up 70 - 90% of the river. Few pools are found in areas where the river has changed its course and left behind a deep channel filled with water.

The most diverse habitat was at Site 5. At this site there is mixing of high-quality water from Eagle Chief Creek with highly mineralized water in the Cimarron. Habitats are along undercut banks, under overhanging salt cedars, in driftwood piles, along many islands, and in long shallow riffles, mainstream pools, and some backwaters. Site 3 had the least diverse habitat. This site consists of 95% shallow riffles with only little pool habitat of 0.1- 0.2 m depth. During dry periods, there was no water at this site.

ENVIRONMENTAL INFLUENCES

Environmental factors that could influence fish communities of the Cimarron include nutrient loading from 38 municipal and 12 industrial discharges into the river drainage in Oklahoma. The major tributaries with elevated nutrient loads are Cottonwood and Skeleton Creeks. As noted, urban and farmland storm runoff from non-point sources also adds to the nutrient loading. The Cottonwood Creek watershed, which includes the Chisholm, Bluff, and Deer Creek tributaries, is now undergoing intensive upgrading (7).

The level of total dissolved solids in water influences fish populations. The Cimarron is the most highly mineralized river in the Arkansas River Basin, with chlorides and sulfates derived primarily from non-point sources.

At non-flow condition or periods of low flow, the pool habitats available to the fish are subjected to large temperature extremes and rapid algae growth. This provides high dissolved oxygen levels during the daylight periods, but a decrease in such levels after dark as the decay of organic waste and respiration continues in these pools.

The fine reddish silt deposited in all backwater areas has a high benthic oxygen demand, and both invertebrates and vertebrates typically were absent from these areas because of low dissolved oxygen levels.

The major recreational uses for the river from Site 5 downstream are fishing and swimming, which contribute to solid waste and litter problems. At Sites 7 and 8, there is extensive recreational vehicle use which helps to maintain the large sand dunes as fairly loose unconsolidated materials and promotes wind erosion. From Site 5 downstream, fishing is very common, with peak use at high flow. Several commercial minnow operations that use the river might affect fish populations.

Downstream from Site 5 farming is extensive. A number of fish kills have occurred during spring floods, probably a result of farming operations in Cimarron floodplains. However, the five major fish kills at Site 4 during the past ten years have usually occurred when the flow was very low, mostly from subsurface water that has emerged with high mineral content. The mineral levels during these kills have exceeded 20×10^3 mg/L dissolved solids at low-flow periods (8).

WATER QUALITY

The Cimarron River has very hard water, with moderate to high turbidity. Elevated amounts of dissolved minerals derive from rocks and salt plains or from petroleum waste and other non-point runoff sources in the stream basins. Moderate to high chlorides and sulfates are characteristic of the Cimarron. The sources of the chloride are salt deposits and salt plains with salt seeps and springs, while the sulfates come from solution of gypsum rocks. Throughout the Cimarron Basin there is a precise relationship between dissolved solids and stream flows (OSDH unpubl. rep.). Stream water during periods of low flow or between rainfalls may contain relatively large amounts of dissolved solids. Stream water during these periods is primarily ground water seepage or discharge, and the slow movement of water through rocks and soils permits ample time for the solution of minerals.

METHODS

Besides the ten long-term fish monitoring sites, an additional five tributaries and six lakes were sampled. Sampling locations (Table 1) were selected on the basis of road accessibility and suitability to the ecoregions found in the river basin.

Fishes were collected from May 1976 through November 1986. Fish communities were sampled two or three times a year at all ten stations to determine relative species abundance, species composition, and population structures at selected points seasonally. A 3.3- by 1.3-m heavy-leaded seine with 3.0 mm mesh was always used to ensure standardized sampling. A 200-m reach of stream was sampled during each visit. To guarantee standard sampling the author acted as leader for all seining trips during the study. The sampling technique consisted of slow seining from the upstream boundary 200 m to the downstream boundary, as close to shore and cover as possible. As in most such sampling there is bias; this method would undersample certain open-water or deep-channel species. Whenever possible, the sampling stations were situated in water less than 1.3 m deep. Fluctuations in water level necessitated some relocation of the segment of shoreline sampled. An attempt was made to take 20 seine hauls of 10-m length during each visit, covering the same area. About one hour of effort was made at each site. In addition to seining, a 33-m, 1.6- by 2.5-cm-mesh monofilament nylon gill net was placed across the site for two hr.

During each visit, dissolved oxygen (DO) was measured with a YSI Model 54A oxygen meter. Water and air temperatures, Secchi disk readings, and rate of flow were recorded. A 1-L bottle of water was taken and placed on ice for laboratory determination of pH, turbidity, and specific conductance. Information on fish habitat, environmental factors, and major changes taking place at each site along with weather information was recorded in a field notebook. Several 35-mm photographic color slides were made of the area in order to have a permanent picture of each site during each visit over the study period.

TABLE 1. Location of sampling stations used in this study for the period 1976 — 1986.

Site no.	Location	County	Legal description	Period of study	Total years	Number of collections
A.	Cimarron River Stations					
1	North of Kenton	Cimarron	S 04 TS 05NR01E CM	1980—86	6	14
2	East of Kenton	Cimarron	S 11 TS 05NR02E CM	1980—86	6	11
3	South of Englewood	Harper	S 24 TS 29NR26W IM	1981—86	5	9 (Dry 3 Times)
4	East of Buffalo	Woods	S 07 TS 28NR20W IM	1976—86	10	29
5	South of Cleo Springs	Major	S 23 TS 22NR12W IM	1979—86	7	17
6	East of Okeene	Kingfisher	S 16 TS 19NR09W IM	1979—86	7	18
7	South of Dover	Kingfisher	S 14 TS 17NR07W IM	1979—86	7	16
8	North of Guthrie	Logan	S 29 TS 17NR02W IM	1978—86	8	18
9	North of Coyle	Logan	S 07 TS 17NR01E IM	1981—86	5	10
10	South of Perkins	Payne	S 07 TS 17NR03E IM	1976—86	10	28
11	North of Ripley	Payne	S 19 TS 18NR04E IM	1981	1	1
B.	Tributaries					
	Crooked Creek	Beaver	S 23 TS 29NR27E CM	1984	1	2
	Nye, KS		S 09 TS 29NR27E CM	1984	1	1
	Horse Creek—Gage	Beaver	S 04 TS 04NR28E CM	1984	1	2
	Salt Creek—Okeene	Blaine	S 25 TS 18NR11W IM	1986	1	1
	Skeleton Creek—Lowell	Logan	S 29 TS 01NR04W IM	1986	1	2
	Cottonwood Creek—Steward	Logan	S 29 TS 17NR02W IM	1982—86	4	6
C.	Lakes					
	Lake Keystone—Cimarron Arm	Pawnee	S 20 TS 20NR09E IM	1985	1	1
	Boomer Lake—Stillwater	Payne	S 02 TS 19NR02E IM	1980, 84	2	3
	Lake McMurtry—Stillwater	Noble	S 34 TS 20NR01E IM	1980, 84	2	2
	Lake Carl Blackwell—Stillwater	Payne	S 09 TS 19NR01E IM	1980, 84	2	2
	Guthrie Lake—Guthrie	Logan	S 05 TS 15NR02W IM	1980, 83, 86	3	3
	Liberty Lake—Guthrie	Logan	S 01 TS 15NR03W IM	1980, 84	2	2

All fish taken were preserved in 10% formalin in the field and transported to the OSDH Environmental Laboratory in Oklahoma City, Oklahoma. Larger fish collected by gill nets were weighed, measured (total length), and identified in the field. These fish were then wrapped in aluminum foil and iced for transport back to OSDH for analysis for heavy metals and pesticides.

In the laboratory, fish in each collection were sorted and identified by the author. The maximum and minimum total lengths and total weight (biomass) for each species were determined for each collection. The range of lengths, total biomass, densities (fish/m^2), biomass densities (g/m^2), and species diversities based on both numbers of individuals per species and biomass were calculated for each collection. Data were also used to calculate the community rating index of community well-being modified by the author from a similar index by Karr et al. (9).

Fish Community Rating Index (FCRI) developed for the OSDH has many of the same parameters as Karr's index (9). However, the OSDH index was expanded to include diversities (biomass and numerical), accumulated species count, proportion of fish to species in a sample, number of species making up 75% of population, and the percentage of rough fish. This index also eliminates two of Karr's parameters, the number of hybrids and the number of diseased fishes (Table 2). The OSDH index was developed for use in all Oklahoma waters; the criteria for each value are contained in an OSDH report (10).

All specimens were placed in 70% ethanol for transfer to and permanent storage at the Oklahoma State University Zoology Museum in Stillwater, Oklahoma. All field notes, slides, and other collection information are available from OSDH in Oklahoma City.

RESULTS AND DISCUSSION

This study of the fish communities in the Cimarron River is based on 198 collections from 23 sites from 1976 to 1986. The collections included 12 families, 50 species, and 347,902 specimens from 11 mainstream sampling sites of the Cimarron (Table 3). Cross et al. (5) reported 16 species from the Cimarron in Mortin, Grand, Seward, Meade, and Clark Counties in Kansas from 1955 to 1983 during 17 sampling trips. Crooked Creek, a large tributary of the Cimarron River that enters Oklahoma in Beaver County, yielded 19 species during the period 1941-1943 from four trips (5). Some related work has been reported (12).

Sixteen collections in the major tributaries included 27 species and 4,036 specimens (Table 4). Six reservoirs produced 30 species and 3,142 specimens during 12 collection trips (Table 5). Only two species (*Ictalurus furcates* and *Percina caprodes*) were found in the reservoirs that were not collected from the mainstream of the river.

SPECIES COMPOSITION

High salinity, long periods of low or no flow, and fairly uniform fish habitat help to restrict to 50 the number of species that occur in the river. Species composition of the river undergoes distinct longitudinal differences in number and ichthyofaunal associations from the headwaters to Lake Keystone (Table 3). Detailed analysis of individual species will be addressed in a future publication.

The accumulative total number of species (ATS) collected at each sampling site increased downstream as the river increased in size and carried a larger volume of water with continuous year-round flow. The westernmost Sites 1 and 2 (usually consisting of isolated pools and long periods of no flow) yielded only 13 species during 24 sampling trips (Table 6). During three trips to Site 3, the site was dry. Sixteen species were recorded at this site during nine trips. The highly mineralized river (7.8×10^3 mg/L dissolved solids) at Site 4 yielded 19 total species during 29 collection trips covering ten years from 1976 to 1986. The greatest significant improvement in ATS was recorded at Site 5 south of Cleo Springs where 34 species were taken during 17 sampling trips. This improvement appears related to the large volume of low-mineralized (55 mg/L chlorides) water that enters the river from Eagle Chief Creek at this site. The volume of water supplied was large enough to provide permanent flow throughout the year.

A slight decrease in ATS occurred at Site 6 (29 species) and Site 7 (31 species), reflecting the discharge of highly mineralized water, 10.4×10^3 mg/L chlorides, from Salt Creek east of Okeene. Another decline at Site 9 likely reflects the combined influences of poor water quality from urban storm water run-off and municipal and industrial discharges into Cottonwood and Skeleton Creeks upstream from the Coyle site. The largest number of species found at any site was 43 at Site 10, determined by 28 sampling trips over a ten-year period.

In many natural communities there is a distinct longitudinal difference in total species from headwaters to mouth. In the Cimarron River, there were several peaks and dips which may indicate environmental stress that disrupts the pattern. In the Cimarron River the longitudinal pattern of normal distribution of species likely reflects the gradient in stress from west to east produced by poor water quality and low-flow periods with high mineralization of the water. Comparisons of total species count by ecoregions show that from the upper sections downstream through the lower section there was an increase in ATS (Table 6).

The mean number of species per collection (MSC) followed a pattern similar to that of ATS. There was an improvement downstream from Site 4 east of Buffalo (Table 6). During three autumn samplings at

TABLE 2. Rating items and stream fisheries community rating indexes.

Rating Item	Excellent		Good		Fair		Poor		Very Poor	
					Category					
1. Number of species per sample (attempted)	>200		15—20	3	10—14	6	5—9	9	<5	12
2. Accumulated species per sampling period	>40/site	0	30—40/site	6	20—29/site	12	10—19/site	18	0-0<10/site	24
3. Species diversity based on number of fish* (11)	>2.75	4	2.25—2.75	8	1.75—2.24	12	1.25—1.74	16	<1.25	20
4. Species diversity based on biomass of fish* (11)	>3.00	6	2.25—3.00	9	1.50—2.24	12	0.75—1.49	15	<0.75	18
5. Proportion biomass/number of fish	>1.0	8	0.75—1.0	10	0.50—0.75	12	0.25—0.49	14	<0.25	16
6. Number of darter species	≥4 species	0	3 species	2	2 species	4	1 species	6	0 species	8
7. Number of sunfish species	≥4 species	2	3 species	4	2 species	6	1 species	8	0 species	10
8. Number of sucker species	≥4 species	0	3 species	2	2 species	4	1 species	6	0 species	8
9. Stress—intolerant species	≥4 species	0	3 species	4	2 species	8	1 species	12	0 species	16
10. Percentage of green sunfish/to other sunfish	<10%	4	10—29%	8	30—49%	12	50—80%	16	>80%	20
11. Proportion of fish to species in sample	<50	6	50—249	9	250—449	12	450—650	15	>650	18
12. Proportion of omnivorous (individual) cyprinids	<10%	4	10—24%	8	25—49%	12	50—76%	16	>75%	20
13. Proportion of Insectivorous (individual) cyprinids	>75%	0	50—75%	3	25—49%	6	10—24%	9	<10%	12
14. Number of top carnivores	>10	0	8—10	3	5—7	6	3—4		<3	12
15. Number of species making up 75% of population	≥5	4	4 species	8	3 species	12	2 species	16	1 species	20
16. Percentage of rough fish	<5%	8	5—9%	10	10—14%	12	15—20%	14	<20%	16

$$\bar{d} = \sum_{1}^{s} (n_i/n)\log_2(n_i/n)$$

Rating index totals:

Add rating indices E____ + G____ + F____ + P____ + VP____ = Reach Score____

46—71=Excellent; 74—122=Good; 123—173=Fair; 174—201=Poor; 202—298=Very Poor; 299=No Fish

TABLE 3. Composition of the fish communities at 10 stations on the Cimarron River, Oklahoma for survey 1976 — 1986.

Species	Station number (times collected and number collected)										Summary		
	1	2	3	4	5	6	7	8	9	10	No. sta.	Times coll.	Total no.
Lepisosteidae (gars)													
Lepisosteus oculatus	0—0	0—0	0—0	0—0	0—0	0—0	0—0	1—1	0—0	0—0	1	1	1
Lepisosteus osseus	0—0	0—0	0—0	0—0	5—13	6—19	2—2	1—3	3—11	6—15	6	23	62
Lepisosteus platostomus	0—0	0—0	0—0	0—0	0—0	1—1	0—0	1—1	0—0	2—3	3	4	5
Clupeidae (shads)													
Dorosoma cepedianum	0—0	0—0	0—0	0—0	6—23	5—88	11—391	10—187	5—42	23—667	6	60	1330
Cyprinidae (minnows)													
Campostoma anomalum	13—466	9—707	1—1	0—0	0—0	0—0	0—0	1—15	0—0	0—0	4	23	1188
Ctenopharyngodon idella	0—0	0—0	0—0	0—0	1—1	0—0	0—0	0—0	0—0	0—0	1	1	1
Cyprinus carpio	1—2	0—0	3—7	4—14	5—32	6—158	3—547	9—98	3—20	12—73	9	56	934
Hybognathus placitus	1—7	1—1	7—389	22—2548	17—3872	18—8377	16—13951	18—21994	9—9543	27—37669	10	136	98,371
Hybopsis aestivalis	0—0	0—0	0—0	0—0	0—0	0—0	0—0	0—0	0—0	1—5	1	1	5
Hybopsis gracilis	8—127	2—11	0—0	0—0	1—1	0—0	2—2	0—0	0—0	0—0	4	13	141
Hybopsis storeriana	0—0	0—0	0—0	0—0	2—7	0—0	0—0	0—0	0—0	1—3	2	3	10
Notemigonus chrysoleucas	0—0	0—0	0—0	0—0	1—1	2—2	1—20	5—8	4—5	2—4	6	15	20
Notropis atherinoides	0—0	0—0	0—0	1—2	11—334	7—77	10—132	16—1209	10—630	28—1989	7	83	4471
Notropis bairdi	0—0	1—260	4—169	7—1876	10—3660	14—4215	14—6477	12—10419	10—5242	25—27268	9	95	59,581
Notropis blennius	0—0	0—0	1—4	0—0	4—30	3—7	2—8	2—13	0—0	5—8	6	17	70
Notropis boops	0—0	0—0	0—0	0—0	0—0	0—0	0—0	1—2	0—0	0—0	1	1	2
Notropis buchanani	0—0	0—0	1—12	0—0	0—0	0—0	0—0	1—1	0—0	4—66	3	5	79
Notropis girardi	0—0	0—0	1—2	5—75	10—193	6—502	71—567	7—187	3—127	16—968	8	55	3,496
Notropis lutrensis	14—8008	11—3771	7—323	14—157	15—7081	11—958	17—8012	19—5892	10—2494	27—6552	10	145	43,248
Notropis stramineus	14—8569	11—4705	6—2130	20—5571	13—996	13—1061	9—1231	9—1179	1—5	15—3100	10	111	28,547
Notropis volucellus	0—0	0—0	0—0	0—0	1—4	3—7	1—1	1—66	1—3	2—13	6	9	94
Phenacobius mirabilis	10—202	4—57	0—0	0—0	6—39	2—4	5—17	5—14	2—8	3—3	8	37	344
Pimephales promelas	14—12392	11—2414	4—281	3—5	9—122	5—10	5—39	10—27	3—7	7—25	10	59	14,338
Pimephales vigilax	1—1	1—2	0—0	0—0	1—1	1—2	1—1	8—27	4—6	9—95	8	26	115

TABLE 3. Continued.

Species	Station number (times collected and number collected) 1	2	3	4	5	6	7	8	9	10	Summary No. sta.	Times coll.	Total no.
Catostomidae (suckers)													
Carpiodes carpio	0—0	0—0	0—0	2—6	2—17	1—1	10—101	9—107	4—30	19—397	7	47	659
Carpiodes cyprinus	0—0	0—0	0—0	1—1	0—0	0—0	0—0	0—0	0—0	0—0	1	1	1
Ictiobus bubalus	0—0	0—0	0—0	2—8	1—10	1—5	4—7	5—64	3—20	9—655	7	25	763
Ictiobus cyprinellus	0—0	0—0	0—0	0—0	0—0	0—0	1—1	1—1	0—0	4—8	3	6	10
Ictaluridae (catfishes)													
Ictalurus melas	2—13	3—17	0—0	0—0	1—1	0—0	0—0	1—17	0—0	1—1	5	8	49
Ictalurus natalis	11—86	2—102	1—1	1—1	1—2	0—0	0—0	1—1	0—0	0—0	5	17	193
Ictalurus punctatus	0—0	0—0	1—1	1—6	8—57	2—33	4—33	8—20	5—15	10—25	8	39	190
Pylodictis olivaris	0—0	0—0	0—0	0—0	1—1	0—0	0—0	3—3	2—2	2—3	4	8	9
Cyprinodontidae (topminnows)													
Fundulus zebrinus	14—7433	11—15907	7—3443	29—40716	17—6144	18—4151	14—560	19—344	9—156	22—179	10	160	79,033
Poeciliidae (livebearers)													
Gambusia affinis	0—0	0—0	6—242	17—1905	14—1148	15—3948	14—721	17—1367	9—830	25—10077	8	117	20,238
Atherinidae (silversides)													
Menidia beryllina	0—0	0—0	0—0	0—0	1—1	2—4	2—2	1—2	1—1	5—44	6	12	54
Percichthyidae (temperate bass)													
Morone chrysops	0—0	0—0	0—0	0—0	2—2	0—0	1—4	7—10	0—0	6-9	4	16	25
Morone saxatilis	0—0	0—0	0—0	0—0	0—0	0—0	0—0	0—0	0—0	3-4	1	2	3

TABLE 3. Continued.

Species	Station number (times collected and number collected) 1	2	3	4	5	6	7	8	9	10	Summary No. sta.	Times coll.	Total no.
Centrarchidae (sunfishes)													
Lepomis cyanellus	7—97	6—32	0—0	5—51	10—93	10—172	4—40	5—34	4—11	11—91	9	62	621
Lepomis humilis	0—0	0—0	1—1	0—0	0—0	3—4	6—21	4—8	1—1	5—7	6	19	42
Lepomis macrochirus	0—0	0—0	0—0	2—16	4—13	6—17	6—58	11—48	6—24	16—90	7	51	266
Lepomis megalotis	0—0	0—0	0—0	3—5	4—11	4—9	5—8	8—72	6—15	15—64	7	45	184
Lepomis microlophus	0—0	0—0	0—0	0—0	0—0	0—0	0—0	3—10	1—1	5—12	3	11	33
L. cyanellus × L. humilis	0—0	0—0	0—0	0—0	0—0	0—0	0—0	0—0	0—0	1—1	1	1	1
L. cyanellus × L. macrochirus	0—0	0—0	0—0	0—0	0—0	0—0	0—0	0—0	0—0	2—2	1	2	2
Micropterus punctulates	0—0	0—0	0—0	0—0	0—0	0—0	0—0	0—0	0—0	1—1	1	1	1
Micropterus salmoides	0—0	1—4	0—0	3—5	4—4	2—4	1—1	4—11	3—4	11—17	8	29	50
Pomoxis annularis	0—0	0—0	0—0	0—0	1—1	1—2	8—17	4—13	3—7	12—46	6	29	86
Pomoxis nigromaculatus	0—0	0—0	0—0	0—0	0—0	0—0	0—0	1—1	0—0	3—5	2	4	6
Percidae (perches)													
Etheostoma cragini	0—0	0—0	5—56	0—0	0—0	0—0	0—0	0—0	0—0	0—0	1	5	56
Sciaenidae (drums)													
Aplodinotus grunniens	0—0	0—0	0—0	0—0	1—1	1—1	1—1	1—1	0—0	6—9	5	10	13

TABLE 4. Species composition of the fish communities taken from major tributaries of the Cimarron River, 1976 — 1986.

Species	Crooked Creek	Horse Creek	Salt Creek	Skeleton Creek	Cottonwood Creek
	Number of times collected and number of individuals collected				
Lepisosteidae (gars)					
Lepisosteus osseus	0—0	0—0	0—0	0—0	1—1
Clupeidae (shads)					
Dorosoma cepedianum	0—0	0—0	0—0	0—0	1—1
Cyprinidae (minnows)					
Cyprinus carpio	0—0	0—0	0—0	12—12	3—3
Campostoma anomalum	0—0	0—0	0—0	0—0	1—1
Hybognathus placitus	2—9	0—0	0—0	0—0	0—0
Notropis atherinoides	0—0	0—0	0—0	0—0	2—8
Notropis bairdi	0—0	0—0	0—0	0—0	1—2
Notropis lutrensis	3—212	2—5	0—0	2—15	6—171
Notropis stramineus	3—865	1—1	0—0	0—0	0—0
Phenacobius mirabilis	0—0	0—0	0—0	1—1	1—6
Pimephales promelas	2—9	2—116	0—0	0—0	3—7
Pimephales vigilax	0—0	0—0	0—0	0—0	2—3
Catostomidae (suckers)					
Carpiodes carpio	0—0	0—0	0—0	2—2	2—2
Ictaluridae (catfishes)					
Ictalurus melas	1—1	1—899	0—0	0—0	0—0
Ictalurus natalis	1—1	0—0	0—0	0—0	2—3
Ictalurus punctatus	0—0	0—0	0—0	2—3	2—24
Pylodictis olivaris	0—0	0—0	0—0	1—2	0—0
Poeciliidae (livebearers)					
Gambusia affinis	2—2	3—777	0—0	0—0	4—82
Cyprinodontidae (topminnows)					
Fundulus zebrinus	3—1,052	2—176	1—34	0—0	0—0
Centrarchidae (sunfishes)					
Lepomis cyanellus	0—0	3—12	0—0	2—8	6—102
Lepomis humilis	0—0	0—0	0—0	1—1	2—4
Lepomis macrochirus	0—0	0—0	0—0	0—0	2—5
Lepomis megalotis	0—0	0—0	0—0	2—13	4—27
Lepomis microlophus	0—0	0—0	0—0	0—0	1—1
Micropterus salmoides	0—0	0—0	0—0	0—0	1—1
Pomoxis annularis	0—0	0—0	0—0	0—0	1—1
Percidae (perches)					
Etheostoma cragini	2—5	3—156	0—0	0—0	0—0
Total species and count	9—1,156	8—2142	1—34	9—47	21—555

TABLE 5. Species composition and total number of fish collected from reservoirs in the Cimarron Basin, 1976 — 1986.

Number of times collected and number of individuals collected

Species	Boomer Lake	Lake Carl Blackwell	Guthrie Lake	Liberty Lake	McMurtry Lake	Keystone Lake
Lepisosteidae (gars)						
Lepisosteus platostomus	0—0	0—0	0—0	0—0	0—0	1—1
Clupeidae (shads)						
Dorosoma cepedianum	3—78	2—172	1—1	2—11	2—13	1—55
Cyprinidae (minnows)						
Cyprinus carpio	3—0	2—39	2—24	2—13	2—65	1—22
Hybognathus placitus	0—0	0—0	0—0	0—0	0—0	1—1
Hybopsis storeriana	0—0	0—0	0—0	0—0	0—0	1—1
Notemigonus chrysoleucas	1—1	0—0	1—1	0—0	0—0	1—2
Notropis atherinoides	0—0	0—0	0—0	0—0	0—0	1—20
Notropis lutrensis	2—23	2—59	0—0	1—14	1—5	1—53
Notropis stramineus	0—0	0—0	0—0	0—0	0—0	1—13
Pimephales vigilax	0—0	1—1	0—0	0—0	0—0	1—46
Catostomidae (suckers)						
Carpiodes carpio	0—0	2—3	1—8	0—0	0—0	1—24
Ictiobus bubalus	0—0	1—3	0—0	1—3	0—0	1—5
Ictaluridae (catfishes)						
Ictalurus furcates	0—0	0—0	1—10	0—0	0—0	1—2
Ictalurus natalis	0—0	0—0	0—0	1—5	0—0	0—0
Ictalurus punctatus	3—22	2—19	1—3	1—7	2—30	1—7
Pylodictis olivaris	3—11	1—1	0—0	1—1	0—0	0—0
Atherinidae (silversides)						
Menidia beryllina	2—54	1—171	0—0	1—322	1—8	1—62
Poeciliidae (livebearers)						
Gambusia affinis	0—0	0—0	0—0	0—0	0—0	1—20
Percichtyidae (temperate bass)						
Morone chrysops	1—1	2—8	1—11	0—0	1—8	1—27
Morone saxatilis	0—0	0—0	0—0	0—0	0—0	1—13

TABLE 5. Continued.

Species	Number of times collected and number of individuals collected					
	Boomer Lake	Lake Carl Blackwell	Guthrie Lake	Liberty Lake	McMurtry Lake	Keystone Lake
Centrarchidae (sunfishes)						
<u>Lepomis cyanellus</u>	1—1	0—0	1—25	0—0	1—1	0—0
<u>Lepomis humilis</u>	0—0	0—0	1—5	0—0	0—0	1—3
<u>Lepomis macrochirus</u>	2—18	2—6	1—7	2—44	2—16	1—50
<u>Lepomis megalotis</u>	2—6	2—2	1—1	1—10	2—17	1—91
<u>Lepomis microlophus</u>	0—0	0—0	0—0	1—1	2—5	0—0
<u>Micropterus punctulates</u>	1—6	0—0	0—0	0—0	0—0	0—0
<u>Micropterus salmoides</u>	2—10	1—14	1—17	2—6	2—5	1—2
<u>Pomoxis annularis</u>	3—21	2—4	2—82	0—0	1—1	1—10
<u>Pomoxis nigromaculatus</u>	2—2	0—0	0—0	0—0	0—0	0—0
Percidae (perches)						
<u>Percina caprodes</u>	0—0	0—0	0—0	0—0	0—0	1—1
Sciaenidae (drums)						
<u>Aplodinotus grunniens</u>	2—30	1—6	1—1	1—1	0—0	1—1
Total species and count	16—294	15—508	14—196	13—439	12—174	25—531

TABLE 6. Effort by years of total, maximum, minimum, and mean species caught in seines from 1976 to 1986 in the Cimarron River.

Station	Site no.	Total species collected	Species/collection			Annual mean species per collection										
			Max.	Mean	Min.	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Upper section																
N. Kenton	1	13	10	7	5	----	----	----	----	9	9	7	8	6	9	7
E. Kenton	2	14	9	6	5	----	----	----	----	5	9	6	7	6	6	9
	Mean	13	----	6.5	----	----	----	----	----	7	9	6.5	7.5	6	7.5	8
	Total	13	----	----	----	----	----	----	----	----	----	----	----	----	----	----
Upper middle section																
S. Englewood, Ks	3	16	11	7	6	----	----	----	----	----	6	7	9	9	8	7
E. Buffalo	4	19	13	5	1	6	9	5	3	3	3	7	6	2	8	6
	Mean	17.5	----	5.5	----	6	9	5	3	3	4.5	7	7.5	5.5	8	6.5
	Total	28	----	----	----	----	----	----	----	----	----	----	----	----	----	-----
Lower middle section																
S. Cleo Springs	5	34	18	11	5	----	----	----	7	14	10	14	13	9	14	8
E. Okeene	6	29	14	9	3	----	----	----	5	13	11	14	11	11	8	4
S. Dover	7	31	24	12	8	----	----	----	10	11	11	20	15	10	7	6
	Mean	31	----	10.6	----	----	----	----	7.1	12.6	10.3	16.0	12.6	10.0	10.0	6.0
	Total	35	----	----	----	----	----	----	----	----	----	----	----	----	----	----
Lower section																
N. Guthrie	8	40	25	13	8	----	----	10	13	14	15	19	12	10	16	18
N. Coyle	9	28	17	11	9	----	----	----	----	----	10	13	12	11	13	18
S. Perkins	10	43	21	14	9	14	15	16	13	14	13	13	13	14	20	17
	Mean	37	----	12.6	----	14	15	13	13	14	13.6	15	12.3	11.6	16.3	18
	Total	44	25	9.5	1	----	----	----	----	----	----	----	----	----	----	----

Site 4, only 2 or 3 small, shallow, isolated pools of clear water were found. During visits on 10 October 1980, 30 September 1984 and 10 October 1985, only plains killifish, *Fundulus zebrinus*, were collected. The largest number of species taken during any one sampling trip was 25 at Site 8 north of Guthrie on 8th of August 1982. Large numbers of species were recorded at the three lower sites several times during this study, while fewer species were found in the westernmost sites.

SPECIES DIVERSITY

Species diversity was calculated from both numerical and biomass data with the Shannon-Weaver equation as used by Wilhm (11): species diversity

$$\bar{d} = \sum_{1}^{s} (n_i/n)\log_2(n_i/n)$$

where n_i *is* the numerical or biomass proportion for each species and n is the number of species. Diversity computed for each collection from each sampling site was used to calculate the mean $\bar{d}$ over the sampling period.

The diversity index, a ratio of the number of species to number of specimens collected, is influenced by variation in collecting efforts. Site 10 had the most diverse fauna and Station 4, one of the most intensively sampled stations, had one of the poorest diversity indices. The diversity index reveals that Site 4 is numerically represented by a large number of fishes of one or two species *(Fundulus zebrinus, Notropis stramineus).*

Numerical diversity (ND) ranged from 2.58 at Site 7 south of Dover, to zero (Table 7). Zero values were found three times at Site 3 and three times at Site 4. These low ND values were a direct result of the absence of water at Site 3 and the presence of a single species at Site 4 when only one or two small shallow pools remained during the fall sampling.

The largest mean ND, 1.78, was at Site 5. The input of high-quality water from Eagle Chief Creek, year-round flow, and diverse aquatic habitat contributed to the fairly high

TABLE 7. Species diversity values for Cimarron River fish communities.

Station	Site no.	Numerical diversity			Biomass diversity		
		Max.	Mean	Min.	Max.	Mean	Min.
Upper section							
N. Kenton	1	2.06	1.72	1.22	2.39	1.89	0.80
E. Kenton	2	2.13	1.56	0.23	2.07	1.53	0.22
Mean		----	1.64	----	----	1.66	----
Upper middle section							
S. Englewood, Ks	3	2.24	1.33	0.00	1.75	1.20	0.00
E. Buffalo	4	1.97	1.04	0.00	2.14	0.86	0.00
Mean		----	1.16	----	----	1.03	----
Lower middle section							
S. Cleo Springs	5	2.50	1.78	0.64	2.54	1.47	0.61
E. Okeene	6	2.54	1.65	0.64	2.57	1.69	1.19
S. Dover	7	2.58	1.61	0.88	3.27	2.06	1.32
Mean		----	1.68	----	----	1.74	----
Lower section							
N. Guthrie	8	2.34	1.54	0.72	3.09	1.68	0.53
N. Coyle	9	2.27	1.46	0.56	2.25	1.86	1.58
S. Perkins	10	2.51	1.64	0.57	3.50	1.79	0.72
Mean		----	1.54	----	----	1.71	----

ND at this site (Table 7). The lowest mean ND was at Site 4, where high mineralization coupled with low flow yielded a 1.04 value for the period 1976 to 1985. At this same site the greatest range in ND was noted (0.00 - 2.28). The smallest range in ND was found at Site 1.

There is a downstream decrease in mean ND values from Site 1 through Site 4, from 1.72 to 1.04. The decline at Site 4 is followed by rapid increase to 1.78 at Site 5. Downstream from Site 6 through Site 10 a second small decline in values was noted. However, a small improvement in values were noted at Site 10 (Table 7).

The largest single biomass diversity (BD) of 3.50 was recorded at Site 10 (Table 7). The lowest BD, 0.00, was recorded six times from Sites 3 and 4. The largest mean biomass diversity (MBD), 2.06, occurred at Site 7 south of Dover, and the smallest, 0.86, at Site 4. The widest range of BD was at Site 10 (0.72 - 3.50). The smallest range occurred at Site 9 (1.58 - 2.25).

There was a substantial downstream decrease in the MBD from Site 1 to 4, from 1.89 to 0.86. The MBD increased from Site 5 through Site 7, where highest diversity was recorded. Diversities for the lower three sites were very similar (Table 7).

Six of the sites averaged biomass diversities slightly larger than those of the averaged numerical diversities (Table 7). However, only three had substantial differences, the largest at Site 7 with a spread of 0.67. The other seven site diversities were very similar in value.

Examination of diversity values by ecoregion of the river indicates that the average numerical and biomass diversities from the upper, lower middle, and lower ecoregions did not differ substantially from each other. The only mean ND and BD values with any substantial differences occurred in the upper middle ecoregion.

A total of 360,107 fish were collected (Table 8). A mean of 2,144 individuals was collected per site in 172 visits to the sites, 1976 - 86. The largest number of fish collected during any single visit was 11,767 during July 1984 at Site 4. The smallest number collected was from Site 5 in June 1978 when high wind and flood waters made sampling almost impossible and only 42 fish were captured. Three times, no fish were found at Site 3, south of Englewood, KS owing to the absence of water. The largest average number of fish per collection (3,216) was at Site 10. Site 3 averaged only 784 fish per collection. Numbers of individuals collected per visit varied widely at some sites. For example, the number of individuals collected at Site 10 varied from a low of 82 to a high of 11,767.

There was a weak longitudinal trend in numbers of fish collected from the headwaters to Perkins (Site 10). The largest numbers of fish per collection were in the upper and lower ecoregions. The upper ecoregion averaged 2,608 fish for 25 collections and the lower ecoregion 2,520 fish for 54 collections (Table 8). There was a well defined decline in the numbers of fishes in the upper middle and lower middle ecoregion of the river. The high salinity during periods of low flow coupled with very little suitable fish habitat influenced the numbers of fish collected at Sites 3 through 7. The upper middle ecoregion averaged 1,305 fish per visit, while the lower middle ecoregion yielded 1,619.

As would be expected, there was a general inverse relationship to the volume of stream flow and numerical abundance of sites, i.e., at high flow fishes are more diluted in the stream and are more difficult to collect. Generally, rainfall follows seasonal patterns and therefore the population trends reveal some seasonally related pattern. This will be addressed in a future publication.

Little published data exist on fish biomass in warm-water streams of Oklahoma and other Great Plains locations. The largest total biomass for a single collection was 28.7 kg at Site 10 on 8 August 1984. A total of 163 gizzard shad, *Dorosoma cepedianum*, with biomass of 24.576 kg was collected. A minimum of 0.1 kg was recorded several times during the study at four sites. The mean biomass of fishes from ten sites on Cimarron River varied from 3.0 kg at Site 10 to 0.6 kg at Sites 3 and 6 (Table 8).

The mean total biomass for collections declined from headwaters to Site 4, east

TABLE 8. Number of fish collected, densities, and biomass for fish communities in the Cimarron River for period 1976—1986.

Station	Site no.	Number of collections	Total fish collected	Mean number per collection	Mean numerical density (no./m²)	Mean biomass density (g/m²)	Mean biomass (kg.)
Upper section							
N. Kenton	1	14	37,403	2671	1.4	1.1	2.2
E. Kenton	2	11	27,990	2544	1.4	0.6	1.3
Total		25	65,393				
Mean			32,697	2608	1.4	0.9	1.7
Upper middle section							
S. Englewood, Ks	3	9	7,062	784[a]	0.4	0.3	0.6
E. Buffalo	4	29	52,967	1826	0.8	0.6	1.1
Total		38	60,029				
Mean			30,015	1305	0.7	0.5	0.8
Lower middle section							
S. Cleo Springs	5	17	23,915	1406	0.7	1.0	1.8
E. Okeene	6	18	23,939	1329	0.7	0.3	0.6
S. Dover	7	16	33,973	2123	1.1	0.4	0.8
Total		51	81,827				
Mean			27,276	1619	0.8	0.6	1.1
Lower section							
N. Guthrie	8	18	43,473	2415	1.2	1.1	2.2
N. Coyle	9	10	19,310	1931	1.0	0.6	1.1
S. Perkins	10	28	90,075	3216	1.6	1.5	3.0
Total		54	152,858				
Mean				2520	1.3	1.0	2.1

[a]Does not include the three times that this site was dry and had no water.

of Buffalo. A slight decrease was noted from 1.7 kg for the upper ecoregion to 0.8 kg for the upper middle ecoregion. A slight increase to 1.1 kg occurred for the lower middle ecoregion followed by a major increase for the lower ecoregion to 2.1 kg.

The ten sampling sites showed considerable variation in mean biomass, but no particular long-term trends were noted. The lower three stations showed the greatest variation with a range of averages from 1.2 kg at Site 9 to 3.0 kg at Site 10. The two sites in the upper middle ecoregion recorded the smallest variation, between 0.7 and 1.0 kg.

Two types of densities were calculated, numerical density (ND), the number of fish/m², and biomass density (BD), as g/m². Estimated mean ND and BD differed substantially among the sites (Table 8). The greatest disparity in numbers was at Site 4, with a range of 0.1-5.9 fish/m². The largest ND was 5.9 fish/m² recorded 7 July 1984 at Site 4, when 11,752 *Fundulus zebrinus* were collected.

The largest overall mean ND was at Site 10, where the density for 28 trips was 1.6 fish/m². The smallest recorded mean of 0.5 fish/m² was at Site 3 for 10 collecting trips.

Comparison of the ND for the upper and lower ecoregions shows that they were almost equal. However, the upper middle and lower middle ecoregions showed a substantial drop to 0.8 fish/m². This substantial drop was related to absence of water, high mineralization, and uniform habitat during the period of low flows.

The estimated average biomass densities (BD) differed substantially among stations (Table 8). The greatest disparity in BD was at Site 10 with a range of 0.1 - 14.4 g/m². The largest BD was 14.4 g/m² on 13 August 1984 when 163 *Dorosoma cepedanium* with a biomass of 24.576 kg were captured. The largest mean BD was at Site 10, with a BD of 1.6 g/m² for 28 collections.

The upper and lower ecoregions showed very similar BD of 0.9 g/m², while the upper middle and lower middle ecoregion BD values were much lower. The downstream trends showed considerable variation without any particular trend being noted.

The cumulative BD for the river was variable from headwaters to downstream. The values reflected several environmental factors that have influenced the fish communities. From Sites 1 to 4 there was a steady decline in BD related to low-flow regime during the late summer and fall at Sites 2 and 3. It seems likely that highly mineralized water at Site 4 combined with low water level has resulted in a small BD. It is likely that influence of high-quality water from Eagle Chief Creek along with a fairly diverse habitat has resulted in an increase in BD at Site 5. Poor water quality of Salt Creek entering the river near Site 6 probably accounted for another decline in BD at Sites 6 and 7. The influence of Cottonwood and Skeleton Creek is reflected in dropping of BD at Site 9. Most likely, the large BD at Site 10 was due to the greater volume of water and greater habitat diversity.

TABLE 9. Fish community rating values for the Cimarron River based on sixteen parameters (10).

Station	Site no.	Fish community rating values		
		Min.	Mean	Max.
Upper section				
N. Kenton	1	167	185	207
E. Kenton	2	173	192	231
Mean		----	188	----
Upper middle section				
S. Englewood, Ks	3	145	179	300
E. Buffalo	4	155	189	216
Mean		----	184	----
Lower middle section				
S. Cleo Springs	5	134	163	194
E. Okeene	6	129	174	206
S. Dover	7	129	160	190
Mean		----	166	----
Lower section				
N. Guthrie	8	110	159	190
N. Coyle	9	139	163	184
S. Perkins	10	120	153	179
Mean		----	155	----

Rating Scale:46—71=Excellent; 74—122=Good; 123—173=Fair; 174—202=Poor; 202—298=Very Poor; 300=No Fish

Table 9 contains the parameters and their assigned values for the FCRI (10).

The fish communities of the river rated by FCRI at Sites 1 through 4 are only "poor" fish communities. Sites 5 and 7 through 10 were ranked as fair locations as water quality data indicate they should be. This trend would be expected since the size of the river increases and there is more diverse fish habitat available.

A large decline at Site 6 reflects the influence of the high salinity of Salt Creek. It was noted that peak values at Sites 2, 4, 6, and 9 reflect the influence of environmental factors on the fish communities. The peaks show that certain factors have likely influenced the type of fish community that has been established at each of these sites.

The six sites located in the lower middle and lower ecoregion were rated fair, consistently being between 153 and 163, with exception of Site 6 at 174, which was poor (Table 9). The highest community rating of 153 was Site 10. Site 2, with low flows most of the year and a fairly poor habitat for fish, had a rating of 192 (poor).

An in-depth discussion of the distribution of each species will be included in a later publication. This report will cover only briefly the species composition of each fish community in the Cimarron River.

The percentage of Cyprinidae (minnows) increased downstream after a substantial decline in the upper middle ecoregion (Sites 3 and 4). The smallest cumulative percentage was at Site 4, where only 25 of fish were minnows. Downstream, Sites 7 through 9 showed 94% of all fish as minnows, while collections from Sites 2 through 4 contained less than 45% minnows. Sites 1 and 5 through 10 showed between 68 and 94% minnows (Table 10).

The omnivorous minnows (such as *Hybognathus placitus, Notropis stramineus, Pimephales promelas, and Fundulus zebrinus)* occurred in fairly large numbers and made up large percentages of all fishes at Sites 1 and 7 - 10. At the middle sites 2 -5, the percentage of these was lower, ranging from 18% at Site 4 to 39% at Site 3. The largest percentage was at Site 8, where 54% were omnivorous minnows. By contrast, the 18% of such fish at Site 4 was the smallest proportion observed on this tropic level. The lower ecoregion showed the highest one, with 51% minnows.

Insectivorous minnows showed a well defined trend downstream. The numbers as well as the percent of total population increased. Both upper ecoregions recorded small numbers and percentages of insectivorous minnows, with percentage ranges from 40% at Site 4 to 22% at Site 1. The lower two ecoregions were fairly similar, with a range from 25% at Site 6 to 49% at Site 5. The smallest percentage of 4% occurred at Site 4 and largest (49%) at Site 5.

Herbivorous minnows were rare throughout the drainage except at Sites 1 and 2, where 1 to 2% of the population was of this tropic level. At all other sites the number was less than 1% of all fish. The large numbers of *Campostoma anomalum* at these upper sites account for the numbers of herbivorous minnows.

Other omnivorous fishes showed an opposite trend from the omnivorous minnows, the largest percentages being recorded in the headwaters at Sites 1 through 4. A range from 75% at Site 1 to a high of 91% at Site 4 was noted. The six lower sites showed almost the same percentages, from 48% at Sites 5 and 7 and a high of 55% at Sites 6 and 8. The two upper ecoregions showed percentages of 79 to 96%, while values for the lower two ecoregions ranged between 50 to 52% of all fishes.

The lower two ecoregions recorded very similar counts for both insectivorous and omnivorous fishes. The range was from 43% at Site 6 to 51% at Site 5. The upper two ecoregions recorded much lower percentages, ranging from 8% at Site 4 to 22% at Site 1. There is a well defined pattern for this level between the upper sites and those downstream sites (Table 10).

Herbivorous fishes were mainly gizzard shads, *Dorosoma cepedianum,* which were found in fairly large numbers at Sites 7 through 10 but never comprised over 1% of the populations. However, *Campostoma anomalum,* which was limited to Sites 1 and 2, comprised between 1 and 2% of all fishes taken at these sites.

Top carnivores such as large mouth bass and longnose gar comprised less than 1% of all fish captured during the study. Sites 1 through 4 did not produce any of this level until the spring of 1987, when extensive flooding washed these species from the lakes and ponds into the river. The carnivores showed a downstream increase in numbers, but comprised less than 1% of the population.

The lower three sites produced the largest numbers of rough fishes. The rough fishes comprised between 1 and 2% of all fishes. At Site 7 this group of fishes comprised 3%. Sites 1 and 2 in headwaters did not produce any rough fishes, but Sites 3 and 4 showed a small number.

The numbers of sport fishes also followed a downstream trend of increasing numbers. At Site 3, only 2 sport fishes were captured, whereas at Site 10, 300 sport fishes were taken during the study.

Indices of similarity were computed to determine similarity in species occurrences between stations along the Cimarron River. *S* was calculated with the formula given by Odum (13):

$$S = 2C/(A + B)$$

where *S* equals the degree of similarity, A and B equal the numbers of species in Samples A and B, and C equals the number of species common to both collections. These values range from zero if no species are in common to 1.00 if all taxa are shared

TABLE 10. Cumulative totals of fishes by tropic levels indicated by total numbers and percentages from survey of ten Cimarron River sampling sites for the period 1976 — 1986.

Location	Site no.	Cyprinid fishes							All fishes											
		CYP F[1]	%	TF[2]	OMN N[3]	%	INST N[4]	%	OMN N[3]	%	HERB N[5]	%	INST N[4]	%	TC N[6]	%	RF N[7]	%	SF N[8]	%
Upper section																				
N. of Kenton	1	27,824	78	35,274	19,597	55	7,762	22	26,943	76	465	1	7,866	22	0	0	0	0	104	<1
E. of Kenton	2	11,045	41	26,877	6,536	24	3,806	14	22,346	83	703	2	3,828	14	0	0	0	0	22	<1
Total		38,869	68	62,151	26,133	42	10,568	17	49,289	79	1,168	2	11,694	19	0	0	0	0	126	<1
Upper middle section																				
S. of Englewood, Ks	3	3,153	45	6,867	2,705	39	447	6	6,124	89	1	<1	742	10	0	0	5	<1	2	<1
E. of Buffalo	4	9,971	22	46,216	8,131	18	1,840	4	42,898	91	0	0	3,814	8	4	<1	29	<1	153	<1
Total		13,124	26	53,083	10,836	21	2,287	4	49,022	96	1	<1	4,556	9	4	<1	34	<1	155	<1
Lower middle section																				
S. of Cleo Springs	5	15,382	72	21,178	4,885	23	10,496	49	10,197	48	24	<1	10,932	51	10	<1	82	<1	148	1
E. of Okeene	6	15,440	68	22,456	9,604	42	5,836	25	12,484	55	88	<1	9,857	43	27	<1	9	<1	242	<1
S. of Dover	7	31,924	94	33,858	15,774	40	16,150	47	16,444	48	391	1	16,998	50	25	<1	1,049	3	185	1
Total		62,746	81	77,486	30,262	39	32,482	42	39,125	50	503	1	37,767	49	71	<1	1,140	1	578	<1
Lower section																				
N. of Guthrie	8	40,497	94	42,717	23,260	54	17,237	40	23,783	55	184	<1	18,715	43	35	<1	459	1	202	1
N. of Coyle	9	17,841	94	944	9,600	50	8,241	43	9,820	51	37	<1	9,067	47	20	<1	118	<1	68	<1
S. of Perkins	10	76,149	88	88,443	43,425	48	33,171	39	44,799	49	610	<1	42,645	49	100	<1	1,726	2	300	<1
Total		134,527	89	132,104	76,425	61	58,649	39	78,602	52	831	52	70,427	47	158	<1	1,293	1	570	<1

1 CYPF = Cyprinid fish
2 TF = Total fish
3 OMN N = Omnivorous number
4 INST N = Insectivorous number
5 HERB N = Herbivorous number
6 TC N = Top carnivore number
7 RF N = Rough fish number
8 SF N = Sportfish number

by two locations.

The *S* indices of the Cimarron fish communities for the 10 mainstream sites indicate that stations varied from high to low but usually had values less than 0.60 (Table 11). Low to moderate similarity (below 0.60) was observed between stations 1-3, and the downstream stations 5-10. High similarity (>0.80) were observed between stations 5 and 10.

The highest similarities (>0.90) were between stations 6 and 7 (0.918) and 6 and 9 (0.912). The lowest observed similarities (<0.40) were between stations 2 and 10 (0.385) and 1 and 10 (0.393). The similarity between upstream and downstream stations indicates improvement in stream conditions downstream of stations 3 and 4.

TABLE 11. Similarity of fish collections from the Cimarron River.

Station									
2	0.889								
3	0.552	0.533							
4	0.500	0.545	0.629						
5	0.511	0.458	0.444	0.679					
6	0.429	0.512	0.533	0.708	0.857				
7	0.444	0.478	0.500	0.694	0.879	0.918			
8	0.453	0.481	0.536	0.610	0.838	0.841	0.833		
9	0.439	0.476	0.478	0.723	0.839	0.912	0.867	0.824	
10	0.393	0.385	0.441	0.548	0.805	0.806	0.800	0.867	0.789
Station	1	2	3	4	5	6	7	8	9

SUMMARY

Ten stations in a large Oklahoma river were studied for a ten-year period from 1976 to 1986. Fifty species were collected from four basic ecoregions of the river. These four major ecoregion types consisted of the headwaters in High Plains (upper section), intermittent stream in Western Plains (upper middle), midstream type in Central Reddish Prairie (lower middle section), and the downstream type in the Cross Timbers (lower section). These communities of fishes were examined for differences in species list, relative numbers, relative biomass, densities, diversities and Fish Community Rating Index (FCRI).

Number of species varied from 12 in the upper section to 43 at the most downstream site. A large change in number of species was between Sites 4 and 5 (upper middle and lower middle sections).

Faunal list, species counts, total numbers, total biomass, diversities (numerical and biomass), and densities (numerical and biomass), as well as FCRI and trophic levels composition were calculated and examined for spatial (headwaters to downstream) trends. Most of these parameters showed some such trends.

Spatial variability in many fish community parameters observed in this work can be likely related to some specific habitat or water-quality problem of either natural or manmade origin. Long-term studies are required to distinguish natural causes from man-induced changes. It is shown that natural disturbances (fluctuations in stream flow) interact with anthropogenic disturbances to control spatial patterns in Cimarron River fish communities.

The study of downstream changes in the fish communities shows that significant differences existed between the headwaters and lower reaches of the Cimarron River with respect to number of species, number of fishes, biomass, numerical diversity, and biomass diversity.

In this study 50 species of fish were taken in 198 field collections, five of which occurred at all stations. Several species found in low numbers had limited distribution. Four species of Cyprinid fishes, *Notropis bairdi*, *Notropis lutrensis*, *Hybognathus placitus,* and *Pimephales promelas,* along with *Fundulus zebrinus* comprised the majority of the numbers and biomass at each station. The greatest disparity in numbers and biomass was primarily between stations 4 and 10. These five species constituted 79% (273,520 fish) of the total collection (347,902 fish).

Both strong biotic or abiotic factors limit most of the community parameters, but at stations 3 and 4 the most important single factor was probably the availability of water, since the lack of water places strict limitations on space as well as habitat diversity.

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