An Ecological Investigation of the Ichthyofauna of the North Canadian River in Oklahoma: 1976—» 1989

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We made 287 fish collections from 37 sites in the North Canadian River drainage in Oklahoma between 1976 and 1989. Despite extensive cultural alterations of the river, it supports a diverse fish fauna. Fifty-six species were collected. Species composition, abundance, temporal and spatial patterns, and diversity of the fish communities were determined at ten stations. Alterations of these community parameters were most pronounced in areas of urbanization and dewatering, above and below impoundments, in areas of agricultural changes, riparian disturbance, floodplain erosion, changing flow regimes and industrial and municipal sewage treatment plants. Comparisons were made with the fish communities in the Cimarron River, a large river, in central Oklahoma, that is less affected by urbanization.

INTRODUCTION

In 1975, the Oklahoma State Department of Health (OSDH) initiated long-term surveys of fishes in each major river in Oklahoma. This paper summarizes surveys made between 1976 and 1989 on the North Canadian River and compares the results with those of a similar study of the Cimarron River (*1*). The native fishes of these streams appear tolerant to physicochemical stress as a result of adaptation to the relatively harsh prairie-stream environment. Such fishes may be more tolerant of human activities (e.g., urbanization) than other species (*2,3).*

DESCRIPTION of the NORTH CANADIAN RIVER

The river has a total drainage area of 39,399 km². It flows through a long, narrow basin as it traverses the 1,219 km from its source to the mouth. Approximately 61% of the drainage is in Oklahoma, 33% in Texas, and 6% in New Mexico (Fig. 1).

There are six major reservoirs (county, year of dam closure) in the North Canadian drainage: four on the mainstream of the river, Lake Optima (Texas Co., 1966), Canton Lake (Blaine Co., 1948), Lake Overholser (Oklahoma Co., 1919), and Lake Eufaula (McIntosh Co., 1964) and two reservoirs on tributaries of the river, Fort Supply Lake on Wolf Creek (Woodward Co. 1938), and Lake Hefner on Buff Creek (Oklahoma Co., 1947). Lake Hefner is connected to Lake Overholser by the Buff Creek Canal. Additional impoundments include municipal lakes (El Reno, Shawnee Numbers One and Two, Sportsman, Wewoka, Cohee, and Wetumka lakes), 149 small (<16,500 acre feet) Soil Conservation Service lakes, 585 playa lakes in the Oklahoma Panhandle, and six small oxbow lakes in the floodplain of the river.

Environmental Influences

Environmental factors that could influence fish communities of the North Canadian River include nutrient loading from 64 municipal sewage treatment plants with potential daily discharges of 123.8 million gallons per day (mgd) (OSDH, unpublished data). The river between Lake Overholser and Lake Eufaula was rated as the most nutrient-enriched stream in Oklahoma (*5*). More nutrients are added from urban and farmland storm runoff from yards, field crops, feed lots, and pasture land. There are 34 discharges into the river from industries and two discharges from electrical power plants.

We tabulated 67 man-induced factors that could affect the native fish communities (Table 1). Other factors observed during our study were urbanization, impoundments, droughts, storm run-off waters (urban and agricultural), oil field pollution, and increases of flows from sewage treatment plants.

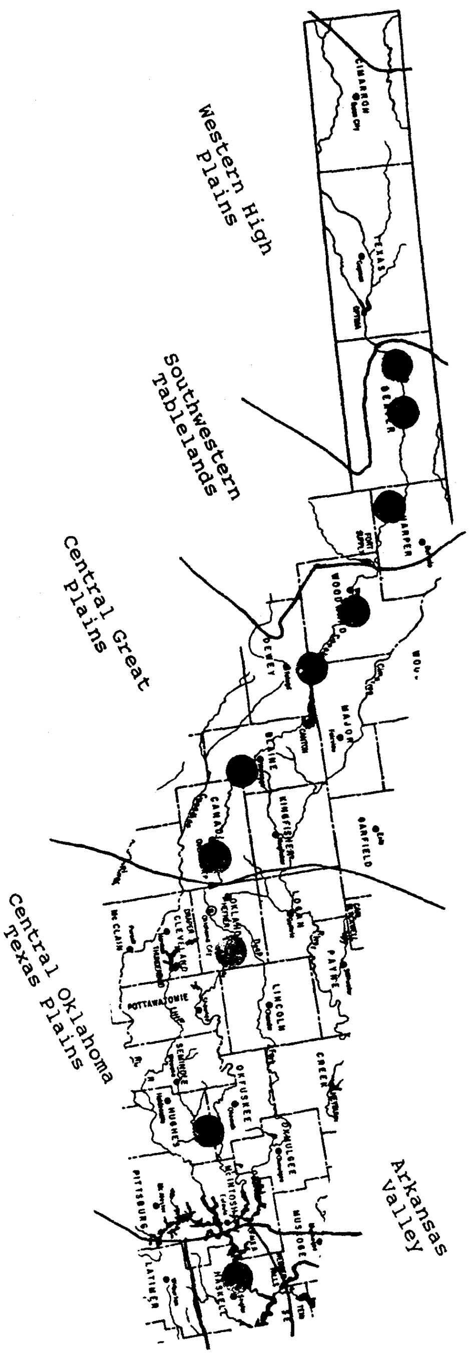

Figure 1. Map of the North Canadian River Sampling Stations and Ecoregions (*4*).

Water Quality

Several tributaries in central Oklahoma contributed contaminants to the river. Crooked Oak Creek has had brine releases and oil spills, which enter the river in Oklahoma County. There were three fish kills in Crooked Creek during the study (OSDH, unpublished data). Soldier Creek flows through Tinker Air Force Base, a major aircraft maintenance center that releases industrial wastewaters. In the past this facility discharged wastewaters high in chromium and organic solvents (*3*). The wastewater enters Crutcho Creek, which flows through highly urbanized Midwest City. It then receives discharges from a secondary sewage treatment plant and drainage from urban storm run-off waters from automobile sale lots and parking lots. Small tributaries such as Lightning, Lime, Brock, and Cherry creeks contribute contaminants during storm run-off from urban areas.

Water of the North Canadian above Hardesty and from Coldwater, Clear, and Kiowa Creeks and other tributaries contained low levels of dissolved minerals (< 400 mg/1). The water in this section is of the calcium carbonate type and is typical of that draining the Ogallala Formation. The North Canadian River above Palo Duro Creek cuts into the Cloud Chief formation and the concentration of dissolved solids exceeded 2,000 mg/1 at Beaver, being high in salt and gypsum levels (*6*).

The water below Oklahoma City (Sites 8 and 9) was also highly mineralized (chloride > 1,420 mg/1). The source of the salt was soluble materials in the mantle rocks upstream and brines from the oil industry. Other organic wastes, such as oil and sewage, were also discharged into the river. These organic and nutrient-laden waters created low levels of dissolved oxygen (<2.0 mg/1), high levels of chlorophyll and eutrophication of the river (Table 2). Throughout this section there has been salt brine seepage from waste pits, defective well casings, and water-flooding operations since 1928.

There were elevated concentrations of metal ions in the water, sediments, and fish tissues during this study. Metals contaminated the river by storm run-off events, salt brine seepage from oil field discharges, discharges from sewage treatment plants, and industrial dischargers; extensive urban and agricultural storm run-off waters contributed to elevated levels of pesticides in the water, sediment, and fish tissues (OSDH, unpublished data).

TABLE 1. Observed environmental factors that might influence fish communities, and the sampling sites where that factor prevailed during 1976 to 1989.

Factor	Site(s)	Factor	Site(s)
Water Quality		**Water Quantity**	
Cattle waste	1–8	Regulation by dams	1–10
Nesting swallows waste	1–5	No water	1–2, 7
Water temp >32 °C	1–5,7–9	No flow	1–2
Turbidity >50 NTU	2–5, 8–9	Below optimum flow	1–4, 7
Low DO <3.0 mg/l)	4, 6, 8–9	Excess flow velocity	4–5, 7–10
Surplus nutrients	4–6, 8–9	> 0.8 m/s	
Heavy metals	4, 8–9	Intermittent flow	1–3
Dissolved solids	1–5	Out-of-bank flooding	3–4, 9–10
Noxious substance	4, 7–9	Irrigation withdrawal	6, 9
Algae	1–3, 6–8	Changing water level	10
Color	7–9	High evaporation rate	1–5
Odor	6–9	Ground water withdrawal	1–5
Organic solvents	8		
		Pollution Sources	
Habitat		*Nonpoint runoff*	
Bridge construction	1–2, 8–10	Hog pens	4
Pipeline crossing	4, 7–8	Grasslands	1–3, 5,8–9
Solid waste	4, 7–8	Gas/oil wells	1–2, 7–10
Old bridge structures	5–6, 8, 10	Gravel removal	1
No pools	1–4, 7, 9	Roadway	1–8, 10
No overhead shading	1–4, 6, 8–10	Urban run–off	2, 4, 6, 8
Poor instream cover	1–3, 6–7	Concrete dump	4
Heavy algae growths	1–4, 6	Pole yard	4
No aquatic vegetation	5, 7–10	Field crops	5, 6, 8–10
Unstable substrate	1–4, 9–10	Auto salvage	5
Bank erosion	3, 7–10	Road construction	1–2, 8–10
Channel modification	1–2, 8–10	Brush clearing	4
Concrete waste	2, 4, 6, 8	Landfills	2, 4–9
		Superfund sites	8
Fish Communities		Feedlot runoff	7
Lack of habitat	1–3		
Fish kills	4, 8–9	*Point Sources*	
Fishing	4–10	Dams	6, 10
Exotic species	8–10	Municipal	4–6, 8–9
Other human activity	4–5, 7–10	Industrial	4–6, 8–9
Physicochemical stress	1–3, 8–9	Power plant	8

METHODS

Between 1976 and 1989 we made 287 fish collections from 37 sites in the North Canadian drainage (Table 3). Fishes at ten sites in the North Canadian River (Fig. 1) were collected from May 1976 through November 1989. Fish communities were sampled two or three times a year for 4 to 13 year intervals, while other sites were sampled more erratically.

At each site a 200-m reach of stream was sampled with a 3.3 × 1.3-m heavily-leaded seine with 3.0-mm mesh during each visit. All seining trips were supervised by one of us (J.P.). The sampling technique consisted of slow downstream seining from the upstream boundary of the sample area, as close to shore and cover as possible. This method under-samples certain open water or deep channel species. During each site visit, we tried to make 20 seine hauls of 10 m length, covering the same amount of surface area and the same segment of the shoreline. About one h of effort was made at each site. In addition to seining, a 33-m, 1.6 × 2.5-cm mesh, monofilament gill net was placed across the site for two h.

During each visit, dissolved oxygen (DO) was measured with an oxygen meter (YSI Model 54A). Water and air temperature, Secchi disk readings, and rate of flow were recorded. A sample of water (a one-liter bottle) was placed on ice for laboratory determination of pH, turbidity, and specific conductance. Information on fish, fish habitat, environmental factors, and major changes occurring at each site, along with

TABLE 2. Water quality (variables that may have influenced fish communities) of the North Canadian River during 1976 to 1989. The sites are those with water quality problems (OSDH, unpublished data).

Parameter	Level of Concern	Units	Sites	Observed range Maximum	Minimum
Dissolved oxygen (DO)	<3.0	mg/l	5,7,8,9	20.0	0.8
Percent saturation (DO)	>120	%	4,5,7,8,9	282.0	12.0
Water temperature	>32	°C	1,2,3,4,5,6,7,8,9,10	36.0	0.0
Carbon dioxide	>10	mg/l	2,5,7,8,9,10	140.0	0.1
Alkalinity	>200	mg/l	1,2,4,5,7,8,9	396.0	8.0
Low pH	<6.0	none	8,9	9.5	4.2
High pH	>9.0	none	2,4,7,9	10.1	4.2
Specific cond.	>2000	µS/cm	1,2,3,4,7,8,9	14800.0	15.2
Ammonia dissolved	>3.0	mg/l	4,8,9	13.0	0.1
Kjeldahl nitrogen	>5.9	mg/l	2,4,5,8,9	25.6	<0.1
Nitrite/nitrate	>10	mg/l	5,8	23.7	0.1
Total nitrogen	>10	mg/l	4,5,8,9	110.0	0.1
Total phosphorus	>3.0	mg/l	5,7,8,9	14.0	0.005
Total chloride	>400	mg/l	2,5,7,8,9	2754.0	3.0
Total sulfate	>500	mg/l	2,5,6,7,8	5100.0	6.0
Turbidity	>50	NTU	2,3,4,5,7,8,9,10	1400.0	1.0
Solids,suspended	>1000	mg/l	2,4,5,7,8,9,10	80000.0	1.0
Solids,dissolved	>2000	mg/l	2,4	2770.0	380.0
Hardness,total	>500	mg/l	2,4,5,7,8,9	1800.0	25.0
Hardness,noncarbonate	>500	mg/l	2,4,5,8	1600.0	0.0
Hardness,calcium	>300	mg/l	2,4,5,7,8,9	1100.0	7.0
Bicarbonates	>250	mg/l	2,4,5,7,8,9	480.0	10.0
Total fluoride	>1.6	mg/l	2,5,9	2.9	0.1
Chemical oxygen demand	>100	mg/l	2,5,7,8,9	450.0	3.0
Total oxygen demand	>50	mg/l	2,8,9	276.0	0.0
BOD, 5 days	>20	mg/l	5,8	140.0	1.0
BOD, 20 days	>100	mg/l	8	147.0	4.5
Chlorophyll a		µg/l	5,8,9	206.2	31.2
Fecal coliform	>400	[a]	2,4,7,8	745000	1
Fecal streptococci	>80000	[a]	4,7,8,9	48000	1

[a] CFU/100 ml.

weather information, were recorded in a field notebook. Further, several 35-mm color photographs were made; the slides permanently record conditions at that visit.

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

In the laboratory, fish in each collection were sorted and identified to species. Maximum and minimum lengths and weight (biomass) for each species were recorded. Standard length, total biomass, densities (fish/m^2), biomass densities (g/m^2), species diversities (based on both numbers of individuals per species and biomass, and a modification (*1*) of Karr's (*7*) index of community well-being) were calculated for each collection.

Species diversity <d> was calculated from both numerical and biomass data with the Shannon-Weaver equation as used by Wilhm (*8*):

$$<d> = -\sum_{i=1}^{s}(n_i/n)\,\log_2(n_i/n)$$

where n_i is the number or biomass of individuals in the *i*th species, n is the total number of individuals or biomass and s is the total number of species.

Diversity was computed for each collection from each sampling site. The individual diversities were used to calculate the mean annual numerical or biomass diversity for a specific site in a given year and the mean numerical diversity (MND) for a specific site over the sampling period.

All specimens were placed in 40:60 2-propanol:water for permanent storage at the Oklahoma State University Collection of Vertebrates. All field notes, photographic slides, and other collection information are available from OSDH, Oklahoma City.

TABLE 3. Location of the sampling stations.

Site Nmbr	Location	County	Legal Description	Eco-region	Period	Nmbr of coll.
A. Long-Term Sites on the North Canadian River						
1	Turpin S on USHW 83	Beaver	S06T03NR21E CM	WT	1981–89	16[a]
2	Beaver N on USHW 270	Beaver	S07T04NR24E CM	WT	1981–89	16[b]
3	May N on OKHW 46	Harper	S23T25NR24W IM	WT	1981–89	16[a]
4	Woodward N on OKHW 34	Woodward	S25T23NR16W IM	CGP	1978–89	30
5	Seiling N on USHW 60	Dewey	S28T20NR16W IM	CGP	1985–89	10
6	Watonga S on USHW 281	Blaine	S27T16NR12W IM	CGP	1978–89	23
7	El Reno N on USHW 81	Canadian	S32T13NR07W IM	CGP	1976–89	40[a]
8	Harrah NW of USHW 62	Oklahoma	S22T12NR01E IM	CGP	1976–89	41
9	Wetumka NE on USHW 75	Hughes	S12T09NR10E IM	COTP	1978–89	26
10	Whitefield N on OKHW 2	Haskell	S12T09NR19E IM	AV	1979–89	23
B. Tributaries and other river sites						
	Cirrumpa Cr State Line	Cimarron	S07T02NR01E CM	WHP	1988	1
	Cirrumpa Cr S Wheeless	Cimarron	S23T02NR01E CM	WHP	1988	1
	Palo Duro Cr SE Hardesty	Texas	S14T01NR18E CM	WT	1988	1
	Palo Duro Cr E Hardesty	Texas	S21T02NR19E CM	WT	1988	1
	Hackberry CR SE Hardesty	Texas	S01T01NR18E CM	WT	1988	1
	Kiowa Cr SW Slapout	Beaver	S12T01NR27E CM	WT	1988	1
	Kiowa Cr W Slapout HW 3	Beaver	S29T02NR27E CM	WT	1988	1
	Kiowa Cr N Slapout	Beaver	S11T02NR27E CM	WT	1988	1
	Beaver R N Laverne HW 281	Harper	S09T26NR25W IM	WT	1987	1
	N. Canad. Little OKHW 56	Pott.	S27T11NR06E IM	CGP	1985	1
C. Lakes						
	Lake Optima Prairie Dog Pt	Texas	S32T03NR18E CM	WHP	1984,87–89	5
	Ft Supply L NE Dam	Woodward	S17T24NR22W IM	WT	1985	1
	Ft Supply L NW Dam	Woodward	S20T24NR22W IM	WT	1985	1
	Ft Supply L Midlake	Woodward	S21T24NR22W IM	WT	1985	1
	Ft Supply L CottonW Pt	Woodward	S29T24NR22W IM	WT	1985	1
	Ft Supply L W CottonW Pt	Woodward	S29T24NR22W IM	WT	1985	1
	Canton Lake at Dam	Blaine	S32T19NR18W IM	CGP	1980,81,84,85,87	8
	Canton Lake Big Bend	Blaine	S20T19NR13W IM	CGP	1985	1
	Canton Lake Blaine Park	Blaine	S27T19NR13W IM	CGP	1985	2
	Canton Lake Longdale Park	Blaine	S15T19NR13W IM	CGP	1985	1
	L Overholser N Dam	Oklahoma	S30T12NR04W IM	CGP	1980,84	2
	L Hefner Intake	Oklahoma	S34T13NR04W IM	CGP	1980,81,86	3
	L Hefner Duck Pond	Oklahoma	S36T13NR04W IM	CGP	1980	2
	Shawnee Lake No. 2	Pott.	S14T10NR02E IM	COTP	1980,85	2
	L Eufaula Oak Ridge	McIntosh	S34T09NR16E IM	COTP	1984	1
	L Eufaula Sherwood	McIntosh	S01T09NR16E IM	COTP	1984	3

[a] Site was dry one time; [b] Site was dry three times.

RESULTS AND DISCUSSION

Our collections included 13 families, 56 species, and 301,456 specimens from 10 mainstream sampling sites of the North Canadian River (Table 4). Ten collections from four tributaries and two river sites not included in the long-term sampling included eight families, 25 species, and 11,199 specimens (Table 4). We collected 41 species and 18,056 specimens from 36 trips to seven reservoirs and one pond (Table 4). All except two of these species (*Notropis volucellus* and *Hiodon alosoides)* were also taken from the river or its tributaries.

Species Distribution

Twenty-two species were widely distributed in the mainstream of the river (Table 5). Eleven species were collected only in the river below Lake Eufaula. Four species tended to be more abundant at downstream sites and were collected from the river between Site 7 at El Reno and above Lake Eufaula. One species, the yellow bullhead *(Ictalurus natalis),* was more abundant at upstream sites. A similar trend was noted for this species in our Cimarron River study (*1*). Two species (*Platygobio gracilis* and *Catostomus commersoni*) were collected only in the headwaters above Lake Optima.

TABLE 4. Summary of OSDH fish collections from the North Canadian (Beaver) River Basin.

Site Nmbr	Location	Number of Collections	Families	Species	Specimens	Biomass (kg)
A. North Canadian River						
1	Turpin	16	7	17	26315	15.9
2	Beaver	16	7	19	16812	15.3
3	May	16	8	24	22352	15.4
4	Woodward	30	11	31	41610	56.8
5	Seiling	10	10	22	3121	5.8
6	Watonga	23	12	29	23638	34.7
7	El Reno	40	10	33	40562	41.7
8	Harrah	41	13	38	64305	115.2
9	Wetumka	26	11	36	59088	39.3
10	Whitefield	23	12	42	3653	13.9
	Total	241	13	56	301456	354.0
B. Tributaries						
	Cirrumpa Cr	2	5	8	645	2.2
	Kiowa Cr	3	4	10	1047	7.3
	Palo Duro Cr SE	2	7	15	8322	4.5
	Hackberry Cr SE	1	6	3	533	3.4
	Beaver N Laverne[a]	1	4	8	598	0.7
	N. Canadian R. Little[a]	1	6	9	54	5.7
	Total	0	8	25	11199	23.8
C. Reservoir/pond						
	Lake Optima	5	11	21	2868	76.4
	Fort Supply Lake	6	10	26	1430	89.5
	Canton Lake	12	11	32	5233	245.0
	Lake Overholser	2	8	15	1315	64.7
	Lake Hefner	3	11	20	805	262.5
	Hefner Duck Pond	2	3	7	77	2.1
	Shawnee City #2	2	9	18	415	56.6
	Eufaula Lake	4	9	23	5913	99.8
	Total	36	13	41	18056	896.6

[a] Site on North Canadian River sampled once.

We ranked 22 of the 61 species as very rare in abundance (Table 5). This ranking indicates that these species occurred in very small numbers; usually less than 19 specimens were collected. In the Cimarron River we listed 13 of 48 species as very rare. (*1*)

Number of Species

Urbanization, impoundments, poor water quality, and fairly uniform fish habitat helped to restrict to 56 the number of species we collected in the North Canadian River. In comparison we found 61 species in the Cimarron River (*1*). On the Illinois River, we listed over 100 species (*9*). In other similar studies we listed 101 species in the Muddy Boggy River (*10*) and 98 species from the Kiamichi River (*11*).

In many riverine fish faunas there is a downstream trend toward increasing numbers of species. The North Canadian River shows a similar trend except for a small decrease at Site 5, which may indicate environmental stress. Despite the highly urbanized nature of Sites 8 and 9 the number of species continued to increase downstream (Table 4). This number increased from the Western High Plains (24 species) to the Western Tablelands (37 species) and Central Great Plains (44 species) and then remained about the same in the more eastern ecoregions (42-45 species).

To compare the total number of species for small tributaries in non-urbanized areas with those of small tributaries in urbanized areas, we used our collections from Cirrumpa, Kiowa, Palo Duro, and Hackberry creeks in Cimarron, Texas, and Beaver counties. These tributaries showed no effects of urbanization. We compared those tributaries with Crutcho, Cherry, and Soldier creeks in Oklahoma County, which are in urbanized areas (*3*). The urbanized

TABLE 5. Species of fish collected in the North Canadian (Beaver) River Basin from 1976 to 1989 classified according to distribution, relative abundance, population stability, and percentage composition.

Species distribution	% of coll.[a]	Rel. Ab.[b]	Δ in pop.[c]	% of fish[d]
Headwater tributaries				
Platygobio gracilis	0	N	X	0
Catostomus commersoni	0	N	X	0
Western (west of El Reno)				
Ameiurus natalis	2	VR	0	<1
Eastern (east of El Reno)				
Lepisosteus platostomus	3	VR	+	<1
Notropis blennius	<1	VR	X	<1
Ictiobus cyprinellus	2	R	X	<1
Tilapia aurea	11	A	–	1
In Lake Eufaula only				
Hiodon alosoides	0	N	X	0
Notropis volucellus	0	N	X	0
East of Lake Eufaula				
Lepisosteus oculatus	<1	VR	X	<1
Alosa chrysochloris	0	N	X	0
Macrhybopsis storeriana	1	VR	X	<1
Lythrurus umbratuilis	<1	VR	X	<1
Ictalurus furcates	<1	VR	X	<1
Fundulus notatus	<1	VR	X	<1
Fundulus olivaceus	1	R	X	<1
Etheostoma spectabile	<1	VR	X	<1
Etheostoma whipplei	2	VR	X	<1
Percina caprodes	<1	VR	X	<1
Percina sciera	<1	VR	X	<1
Widely distributed				
Dorosoma cepedianum	37	A	+	<1
Cyprinus carpio	34	C	–	<1
Hybognathus placitus	30	VA	–	2
Notemigonus crysoleucas	6	R	X	<1
Notropis atherinoides	21	A	–	<1
Cyprinella lutrensis	74	VA	0	50
Notropis stramineus	59	VA	+	6
Phenacobius mirabilis	31	A	+	<1
Pimephales promelas	44	VA	+	3
Pimephales vigilax	54	A	+	1
Carpiodes carpio	37	A	0	<1
Ictalurus punctatus	40	A	+	<1
Fundulus zebrinus	47	VA	+	12
Gambusia affinis	84	VA	+	21
Menida beryllina	17	A	+	1
Morone chrysops	16	C	–	<1
Lepomis cyanellus	43	C	0	<1
Lepomis humilis	16	C	0	<1
Lepomis macrochirus	23	C	+	<1
Lepomis megalotis	43	A	+	<1
Micropterus salmoides	36	C	+	<1
Pomoxis annularis	25	C	+	<1
Sparsely distributed				
Lepisosteus osseus	5	R	+	<1
Dorosoma petenense	<1	VR	X	<1
Campostoma anomalum	2	VR	–	<1
Macrhybopsis aestivalis	1	VR	–	<1
Notropis bairdi	<1	R	X	<1
Notropis buchanani	1	R	X	<1
Notropis girardi	4	C	–	<1
Pimephales notatus	1	VR	X	<1
Ictiobus bubalus	24	A	+	<1
Ictalurus melas	3	VR	0	<1
Pylodictis olivaris	3	VR	–	<1
Labidesthes sicculus	6	R	–	<1
Morone saxatilis	3	R	+	<1
Lepomis gulosus	1	VR	X	<1
Lepomis microlophus	3	VR	X	<1
Micropterus punctulatus	4	R	0	<1
Pomoxis nigromaculatus	3	VR	+	<1
Stizostedion vitreum	<1	VR	+	<1
Aplodinotus grunniens	7	C	0	<1

[a] Percentage of total mainstream collections in which the species appeared.

[b] Relative abundance as follows: VA = over 5,000 specimens; A = 500–4999 specimens; C = 100–499 specimens; R = 20–99 specimens; VR = 1–19 specimens; N = did not occur in mainstream sites.

[c] Change in population. Symbols indicate: + = increasing, – = decreasing, 0 = stabilized, and X = number collected is too small to indicate significant change from 1976 to 1989.

[d] Percentage of all fish collected in mainstream sites for 1976 to 1989.

streams had slightly smaller numbers of species (17 versus 20 species).

The total species count varied substantially in reservoirs, partly as a result of reservoir size (7 species in Hefner Duck Pond to 32 species in Lake Canton). The urbanized lakes (Overholser, Hefner, and Shawnee # 2) in central Oklahoma had smaller numbers of species (15-20 species) than the remaining lakes included in our survey, all of which were less urbanized.

Species Diversity

Sites 3 and 4 had the highest mean numerical diversities (ND = 1.77 and 1.79). Site 7, a very uniform habitat, and Site 9, an altered site, had lowest mean numerical diversities (0.82 and 0.97) (Table 6). Sites 7 and 9 were dominated by one or two species *(Cyprinella lutrensis* and *Gambusia affinis).*

The largest mean ND, 1.79, occurred at Site 4. Sites 3 and 5 also had large mean ND values of 1.77 and 1.70, respectively. The input of a high quantity of water from Wolf Creek, year-round flows, and a diverse aquatic habitat may have contributed to fairly high mean ND values at these sites (Table 6). The smallest mean ND was at Site 7, where a uniform aquatic habitat coupled with long periods of rapid flows resulted in a value of 0.82 for the study period. Mean ND values from the upstream Sites 1 through 5 ranged from 1.44 to 1.79 (Table 6), while lower values occurred in downstream areas (0.82 - 1.15).

TABLE 6. Mean annual numerical diversities for the ten OSHD fish-collecting sites from 1976 to 1989.

	Site number									
Year	1	2	3	4	5	6	7	8	9	10
1976							0.59	1.14		
1977							0.54	1.38		
1978				2.26		0.94	0.82	1.99	0.48	
1979				1.48		0.81	0.54	1.14	0.71	1.43
1980				1.29		1.38	0.61	0.82	0.98	1.97
1981	0[a]	0[a]	0[a]	1.90		1.22	0.62	0.61	1.12	1.82
1982	2.35	1.70	2.12	2.32		1.07	0.76	1.46	1.37	0.76
1983	2.15	2.20	1.17	1.79		1.09	0.97	0.71	1.09	2.31
1984	0.77	0.53[b]	1.85	1.98		1.14	1.10	0.83	1.06	1.08
1985	2.55	1.64	2.11	1.89	2.33	1.63	1.27	1.11	0.67	2.24
1986	1.46	0.50[b]	1.79	1.61	1.08	1.45	0.98	1.49	0.75	1.26
1987	2.13	1.67	1.78	1.55	2.39	0.98	0.94	1.29	1.14	0
1988	1.59	1.85	1.85	1.51	2.03	0.83	0.33	1.52	1.09	1.57
1989	1.77	1.99	1.99	1.89	1.40	0.58	0.93	0.88	0.81	0.96
MND	1.59	1.44	1.77	1.79	1.70	1.14	0.82	1.15	0.97	1.48
MXND	2.52	2.25	2.47	2.57	2.66	2.39	2.10	2.06	1.81	2.70
MIND	0.53	1.00	1.27	0.46	0.55	0.18	0.05	0.19	0.25	0
Ecoregion		WT			CGP		COTP		AV	
MND		1.59			1.36		1.06		1.43	

[a] Site was dry that year; no fish were collected.
[b] Site was dry one time that year and no fish were collected.
MND = Mean numerical diversity by site for the study period.
MXND = Maximum numerical diversity for single collection.
MIND = Minimum numerical diversity for single collection.

TABLE 7. Mean annual biomass diversities (BD) for the ten OSDH fish-collecting sites from 1978 to 1989.

	Site number									
Year	1	2	3	4	5	6	7	8	9	10
1978				2.29		2.07	1.37	1.41	1.17	
1979				1.67		1.19	1.65	0.74	1.13	0.55
1980				1.98		1.71	0.84	1.27	1.39	1.59
1981	0[a]	0[a]	0[a]	2.05		2.10	1.44	0.97	1.89	1.31
1982	2.32	1.82	1.93	1.71		1.49	1.68	1.23	1.21	1.58
1983	2.24	2.10	2.06	2.40		1.81	1.83	0.98	0.98	2.10
1984	0.83	0.62[b]	1.59	1.82		1.65	2.14	1.35	1.42	1.07
1985	1.24	1.83	1.92	1.92	2.38	2.79	1.56	1.02	1.27	2.06
1986	1.69	0.62[b]	1.49	1.62	2.07	2.36	1.63	1.45	1.05	0.78
1987	2.08	2.08	1.44	1.93	1.12	0.73	1.67	1.42	0.92	0
1988	2.00	2.28	1.84	1.88	1.68	0.62	1.04	1.49	1.05	1.94
1989	1.57	2.27	2.01	1.80	1.45	1.15	0.70	0.74	1.04	0.66
MBD	1.60	1.57	1.66	1.89	1.73	1.69	1.29	1.07	1.24	1.27
MXBD	2.54	2.66	2.42	2.86	2.98	2.60	2.60	2.23	2.34	2.66
MIBD	0	0	0	1.28	0.82	0.29	0.29	0.16	0.50	0
Ecoregion		WT			CGP		COTP		AV	
MBD		1.61			1.65		1.16		1.27	

[a] Site was dry that year, no fish were collected.
[b] Site was dry one time that year and no fish were collected.
MBD = Mean biomass diversities for period of record.
MXBD = Maximum mean annual biomass diversity values for that site.
MIBD = Minimum mean annual biomass diversity values for that site.

The maximum biomass diversity (BD) of 2.98 was recorded at Site 5 (Table 7). The largest mean BD, 1.89, occurred at Site 4. The smallest mean BD (1.07) was at Site 8 in the urbanized area. The widest range of BD was at Site 2 and 10 (0.00 - 2.66). The smallest range occurred at Site 4 (1.28 - 2.86).

The mean numerical diversity and the mean biomass diversity for each of the four ecoregions differed insubstantially from each other (0.02 - 0.29).

TABLE 8. Total biomass (TBM) per site, mean biomass (MBM) per collection, and mean biomass (MBMS) for specimens for the ten fish-collecting sites.

Eco-region	Site	TBM (kg)	MBM (g) Max	MBM (g) Mean	MBM (g) Min	MBMS (kg) Max	MBMS (kg) Mean	MBMS (kg) Min
WT	1	15.9	2.5	0.9	0.2	2.1	0.9	0.3
	2	15.3	3.9	0.9	0.2	2.1	0.9	0.2
	3	15.4	2.8	0.9	0.1	1.5	0.8	0.3
	Mean	15.5	3.9	0.9	0.1	2.1	0.9	0.2
CGP	4	56.8	7.7	1.8	0.1	12.0	2.1	0.5
	5	5.8	1.5	0.5	0.1	5.8	2.5	1.0
	6	34.7	3.6	1.5	0.2	7.9	2.0	0.4
	7	35.7	3.9	1.0	<0.1	231.0	16.7	0.2
	Mean	33.3	7.7	1.2	<0.1	231.1	5.8	0.2
COTP	8	115.2	15.4	2.8	<0.1	300.0	16.3	0.1
	9	39.3	10.8	1.5	0.1	3.0	0.7	0.2
	Mean	77.3	15.4	2.2	<0.1	300.2	8.5	0.1
AV	10	13.9	3.2	0.6	<0.1	45.2	10.6	0.6
	Mean	13.9	3.2	0.6	<0.1	45.2	10.6	0.6
Mean for all sites				1.2			5.4	

Mean Biomass

The mean biomass per collection (MBM) increased from the headwaters to Site 8 (0.9—» 2.8 kg) (Table 7). The MBM by ecoregions showed an overall increase downstream, from the Western Tablelands ecoregion to the Central Oklahoma Texas Plains ecoregion (Table 8).

The ten sampling sites showed considerable variation in MBM, but no long term trends were noted. The middle four sites showed the greatest variation, with a range of averages from 0.5 kg at Site 5 to 2.8 kg at Site 8. At the three westernmost sites the MBM was the same (0.9 kg) and had the smallest variation (0.0) between sites. The smallest MBM was 0.5 kg at Site 5.

The maximum biomass per collection was 15.4 kg and occurred on May 18, 1984 when 26 river carpsuckers and seven carp were collected near Harrah at Site 8. The minimum biomass of less then 0.1 kg per collection occurred at Sites 7, 8, and 10. A substantial increase in MBM from Site 1 to Site 8 (0.9 to 16.3 g), appeared to support a longitudinal trend of the MBM downstream. This was expected, since in rivers there are heavier fish in the deeper downstream areas of the river. However, in the urbanized altered sites of the river (Sites 7-9) there was greater fluctuation in the MBM (0.1 - 300.2 g/specimen) (Table 8).

Fish Community Rating Index

The fish community rating index (FCRI) varied from a minimum of 88 (good) at Site 10 to 250 (no fish) at Sites 1 through 3 and 10. All sites rated by FCRI had an occasional "poor" rating (174-202). Most of the time the FCRI was in the "fair" range (123-173) except at Site 10, which sometimes received a "good" rating (74-122).

The mean FCRI for all sites except Site 1 indicated a "fair" fish community throughout the river. At Site 1 the mean FCRI was 175 (poor). The "poor" rating was the result of low flows most of the year, due to the lack of discharges from Lake Optima, and a fairly poor habitat for fish. In the urbanized area the mean FCRI declined slightly to 165 at Site 8 and 164 at Site 9. The best mean FCRI was 146 at Site 10 below Lake Eufaula.

The mean FCRI for the three westernmost ecoregions was very similar, ranging from 156 in the Central Great Plains ecoregion to 170 in the Western Tableland ecoregion. The mean FCRI of the Arkansas Valley ecoregion improved to 148. This trend in FCRI was expected since the size of the river increased and there were more diverse fish habitats available. The mean FCRI for the ten sampling sites was 161 ("fair" fish community). In comparison, the FCRI for the Cimarron River was "poor" for all upstream sites and was "fair" for downstream sites. The longitudinal trend in the Cimarron River was very similar to that in the North Canadian River.

TABLE 9. Cumulative totals of fish food trophic groups, by total numbers and percentage from a survey of the ten OSDH sampling sites.

		Cyprinid fish				All fish							
		OMN		INST		OMN		HERB		INST		TC	
Region	Site	Nmbr	%	Nmbr	%	Nmbr	%	Nmbr	%	Nmbr	%	Nmbr	%
WT	1	4190	16	2411	9	18516	70	0	0	7799	30	0	0
	2	4089	24	3245	19	11265	67	1	<1	5540	33	6	<1
	3	6376	29	7385	33	12864	58	3	<1	9468	42	17	<1
	Total	14655	22	13041	20	42645	65	4	<1	22807	35	23	<1
CGP	4	9508	23	21191	51	14131	34	337	<1	27033	65	109	<1
	5	582	19	1449	46	720	23	107	3	2166	69	108	3
	6	1933	8	14556	62	3980	17	555	2	19019	80	84	<1
	7	1280	3	34700	86	2799	7	397	<1	37302	92	64	<1
	Total	13303	12	71896	66	21630	20	1396	1	85520	79	365	<1
COTP	8	1182	2	26476	41	1787	3	3100	5	59356	92	62	<1
	9	4096	7	44672	76	5805	10	623	1	52527	89	135	<1
	Total	5278	4	71148	58	7592	6	3723	3	111883	91	197	1
AV	10	87	2	524	14	210	6	161	4	2927	80	355	9
All	All	33323	11	156609	52	72077	24	5284	2	223137	74	940	<1

Nmbr=Number; OMN=Omnivorous; INST=Insectivorous; HERB=Herbivorous; TC=Top carnivore

TABLE 10. Cumulative total of fish collected by classes as sport fish, rough fish, intolerant species, and introduced fish indicated by total numbers of species, percentage of fish collected and number of species for the ten fish-sampling sites.[a]

		Rough fish		Sport fish			Intolerant fish			Introduced fish	
Region	Site	Nmbr	%	Nmbr	Spcs	%	Nmbr	Spcs	%	Nmbr	%
WT	1	5	<1	13	4	<1	14320	2	54	3	<1
	2	18	<1	44	6	<1	7163	2	42	8	<1
	3	28	<1	65	9	<1	6585	2	25	15	<1
	Total	61	<1	122	9	<1	28068	2	43	26	<1
CGP	4	574	1	437	11	<1	4311	3	10	82	<1
	5	124	4	204	8	7	82	2	2	541	17
	6	707	3	381	13	2	2044	3	8	155	<1
	7	577	1	795	13	2	1290	3	3	106	<1
	Total	1982	2	1917	13	2	5719	3	5	884	1
COTP	8	859	1	193	15	<1	36	3	<1	3075	5
	9	2085	4	203	13	<1	5	2	<1	379	<1
	Total	2544	2	396	15	<1	56	3	<1	3454	3
AV	10	289	8	401	15	11	51	6	1	1981	54
All		4876		2660	15		33894	6		6345	
% all sites			1.6			0.9			11		2.1

[a] Nmbr=number of fish; Spcs=number of species.

The greatest variation in the FCRI occurred at Site 10, where values ranged from 88 (good) to 250 (no fish). This variability may have been due to sudden changes in the daily water levels below Lake Eufaula. At Site 8, altered by urbanization upstream, the FCRI range was from 129 to 197 (fair-poor). Cimarron River was "poor" for all sites upstream from Site 5 and was "fair" for downstream sites. This trend in the Cimarron River was very similar to that in the North Canadian River in the downstream trend.

Faunal Composition

The omnivorous minnows *Notropis stramineus* and *Pimephales promelas* occurred in fairly large numbers and made up large percentages (16% to 29%) of all fish at Sites 1 through 5 (Table 9). At the down-stream Sites 6 to 10, the percentage of this group was much smaller (2% to 8%). The largest percentage of omnivorous minnows (29%) was at Site 3. By contrast, only 2% of all fish at Site 10 were omnivorous minnows. This was the smallest proportion observed from this group. The mean for all sites was 11%, which was much smaller than the 89% found in the Cimarron River (*1*).

In general, the numbers of insectivorous minnows as well as their percentage of the collections increased in the downstream direction. The three westernmost sites and Site 10 showed the smallest numbers and percentage of insectivorous minnows, the percentage ranging from 9% at Site 1 to 33% at Site 3. Site 10, below Lake Eufaula, had 14%. The largest percentages were at Sites 4 through 9 (Table 9). The largest percentage (86%) was at Site 7. The overall percentage of the insectivorous minnows was 52%, slightly larger than the 39% recorded in our Cimarron River study (*1*).

Herbivorous minnows (*Campostoma anomalum*) were very rare throughout the drainage, except in Cirrumpa Creek, a headwaters tributary in Cimarron County. At the ten mainstream sites *C. anomalum* was collected four times at sites 8-10 and in small numbers (seven total specimens). This group comprised < 1% of all fish collected. The group was rare in our Cimarron River study also but occurred in larger numbers in the main stream of the river than in the North Canadian River.

Other omnivorous fishes showed a trend similar to that of the omnivorous minnows. The largest percentages were recorded in the headwaters at Sites 1 through 4, ranging from 70% at Site 1 to 34% at Site 4. The percentages of omnivorous fishes at Sites 7 through 10 were very similar to each other, ranging from 3% to 10%. In the Western Tableland ecoregion this group of fishes comprised 65% of the total fish. There was a decline to 20% in the Central Great Plains ecoregion and 6% in the urbanized sections (Central Oklahoma and Texas Plains) and the Arkansas Valley ecoregion (Table 9).

The insectivorous fishes showed a well-defined increase in the percentage of fish collected downstream. Insectivorous fishes increased in percentage composition from 30% at Site 1 to 92% at Sites 7 and 8. A small decline to 89% was noted at Site 9, and 80% at Site 10. The large percentage at Sites 8 and 9 was due to the large numbers of *Notropis lutrensis* and *Gambusia affinis* collected. These species accounted for 90% of the insectivorous fish collected.

The percentage of herbivorous fishes increased slightly downstream, from 0.0% at Site 1 to 5.0% at Site 8 and 4.0 % at Site 10. A similar pattern was noted for ecoregion percentages, from <1.0% in the Western Tablelands ecoregion to 4.0% in the Arkansas Valley ecoregion. The increases downstream at Sites 5, 8, and 10 were due to the gizzard shad (*Dorosoma cepedianum*). At Sites 8 and 9, the increase was due to the introduction of the blue tilapia (*Tilapia aurea*) from Horseshoe Lake, a cooling pool for the Oklahoma Gas and Electric Company's Horselake Electrical Generation Plant downstream from Site 8. The only other herbivorous fish was *Campostoma anomalum*, which occurred in small numbers at Sites 8 and 9, comprising <1% of fish collected. The herbivorous fishes were found in 2% of our collections. In our Cimarron River study the herbivorous fishes comprised 1.1% (*1*).

Top carnivores such as largemouth bass and longnose gar comprised less than 1% of all fish captured during the study. The top carnivores increased in numbers downstream (Table 9). Only at Site 5, where they comprised 3%, and at Site 10, where they comprised 10%, did they amount to more then 1% of the fish collected. The largest population (355 specimens) was collected at Site 10, north of Whitefield. Only at Site 1 were we unable to collect this group. Seven sites showed that less then 1% of the fish were top carnivores; nevertheless, we obtained a larger number (940 specimens) from this river than we did from the Cimarron River (158 specimens) (*1*).

Sport fishes increased in numbers of individuals and species in downstream sites. At Site 1 there were 13 sport fish from four species collected. The number increased to 795 sport fish and 13 species at Site 7, with small declines in numbers at Site 5 and 6. The largest number of sport fish species was 15 at Sites 8 and 10. At six sites the sport fish comprised less then 1% of fish collected. At Site 5 this group comprised 6% and at Site 10, 11%. Sport fish totaling 2,660 specimens from 15 species were collected and they made up 0.9% of the fish collected. The most numerous sport fish collected was the longear sunfish (708 specimens) and it was in 43% of the collections from the river (Table 10).

Rough fish comprised 1.6% of the fish collected (4,876 specimens). The number of rough fish taken in this river was slightly larger than the number we found in the Cimarron River (*1*). The largest number of rough fish (2,544 specimens) occurred in the impacted sections of the river (Sites 8 and 9). These fish usually amounted to less than 4% of the total fish collected. The most numerous rough fish was the gizzard shad *(Dorosoma cepedianum),* which comprised less than 1% or 2,219 specimens. The second-most numerous rough fish was the river carpsucker, making up <1% or 1,949 specimens. Site 10 had the largest percentage of both rough fishes (7%) and sport fishes (11%).

We collected six intolerant (to changes in environmental quality) fish species from the river. The number of such species increased downstream, and varied from two at Site 1 to six at Site 10. The number was fairly stable, with two or three such species at each site, except Site 10. The percentage of intolerant fishes varied from 54% at Site 1 to less than 1% at Sites 8 and 9, the urbanized section.

The number of introduced fish taken increased from three at Site 1 to 3,075 at Site 8. At seven sites the percentage of introduced fish was less than 1%. However, at Sites 5, 8, and 10 the percentages were 17%, 5%, and 54%, respectively, of the fish collected. The largest number of introduced fish (3,075 specimens) was at Site 8 in the urbanized section of the river. Two species, *Tilapia aurea* (2,850 specimens) and *Menida beryllina* (151 specimens), comprised most of the introduced fish at Site 8. Six species of introduced fish comprised 2.1% of all fish collected.

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