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Changes in the Canadian River Fish Assemblage Associated with Reservoir Construction

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ABSTRACT

The fish assemblage of the Canadian River in Texas historically was dominated by *Hybognathus placitus* and *Notropis girardi*. These species represented > 90% of fishes collected from the Canadian River in 1954-1955. Construction of two reservoirs on the Canadian River in the 1960s (Ute Reservoir, New Mexico, 1962; Lake Meredith, Texas, 1965) altered hydrologic conditions in the river and affected the fish assemblage. Downstream from Ute Reservoir, mean annual discharge decreased by about 38% after impoundment, but *H. placitus*, *N. girardi*, and other mainstem species still dominate the assemblage. Downstream from Lake Meredith, mean annual discharge decreased by 76% and the historic mainstem fish assemblage has been almost completely replaced by species that formerly were restricted to tributary streams. The magnitude of post-impoundment changes in the fish assemblage of the Canadian River appears to be related to the degree that discharge has declined, especially during the spawning season.

INTRODUCTION

Dams and impoundments alter physical and chemical conditions in streams and rivers, especially in downstream areas (Baxter 1977, Stanford and Ward 1979). Changes in water temperature, substrate, presence of backwaters, and in the timing and volume of discharges may directly affect stream fish populations (Baxter 1977, Holden 1979, Bain et al. 1988). Reduced discharge can result in changes in channel morphology, reducing multiple braided-channels to a single channel (Friedman et al. 1998), that indirectly affect stream fish populations (Patton and Hubert 1993). The effects of these changes are greatest on obligate riverine fishes, those that require streams and rivers for all or part of their life history (Holden 1979).

Demand for water in the Arkansas River drainage has led to the construction of at least 50 major reservoirs in Colorado, Kansas, Arkansas, Oklahoma, Texas, and New Mexico (Limbird 1993). Streams and rivers in the Arkansas River drainage historically were characterized as harsh environments, with erratic summer flows and extremely variable physical and chemical conditions (Dolliver 1984, Matthews 1987). Impoundments have reduced the magnitude of, and variability in, stream flows and other physical and chemical conditions throughout the Arkansas River drainage, particularly since the 1960s. Associated with these changes are dramatic declines in the distribution and abundance of several native stream fishes, especially cyprinids (Cross and Moss 1987, Matthews 1987, Pflieger and Grace 1987, Limbird 1993). Among species

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that have declined most notably in abundance are the obligate riverine species *Notropis girardi, Hybognathus placitus, Macrhybopsis aestivalis*, and *Platygobio gracilis* (Cross et al. 1983, Cross and Moss 1987, Pflieger and Grace 1987, Pigg 1991, Limbird 1993).

In portions of the Canadian River, the southernmost tributary of the Arkansas River, fish assemblages have maintained their historic abundance and composition. However, in other portions of the river, the fish assemblage has changed dramatically following reservoir construction. We report here temporal changes in the fish assemblage of two reaches of the Canadian River, Texas, that are differentially affected by the presence of upstream impoundments.

METHODS AND MATERIALS

The Canadian River originates in the Sangre de Christo Mountains of northeastern New Mexico and southern Colorado and flows 1,510 km east and southeast through New Mexico and Texas to its confluence with the Arkansas River in eastern Oklahoma (Dolliver 1984, Sublette et al. 1990). Four reservoirs are located on the Canadian River (Figure 1). These include Lake Conchas, impounded in 1938 (San Miguel County, NM); Ute Reservoir impounded in 1962, (Quay County, NM); Lake Meredith impounded in 1965 (Potter, Moore, and Hutchinson Counties, TX); and Lake Eufaula impounded in 1963 (Pittsburg, McIntosh, and Haskell Counties, OK). Prior to impoundment, flows in the Canadian River were primarily from high intensity, short duration rainfall events during the summer months (Dolliver 1984). After impoundment, flows were regulated by upstream dams and rainfall.

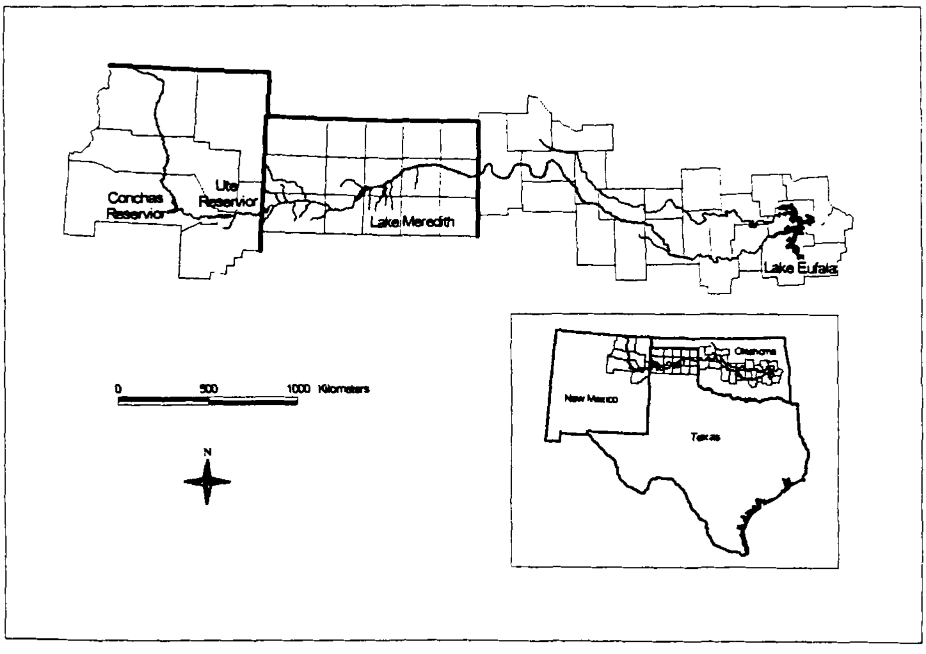

Figure 1. Map of the Canadian River, New Mexico, Texas, and Oklahoma, showing locations of impoundments.

We compiled information on the Canadian River fish assemblage from several unpublished sources and from our collections made in 1995 and 1996. Lewis and Dalquest (1955) conducted an extensive survey of the fishes of the Canadian River from June 1954 through May 1955. They sampled 11 sites in the river, four upstream from present day Lake Meredith, and seven downstream. Four sites (two upstream and two downstream) were sampled monthly; the rest were sampled on one to three occasions. Lewis and Dalquest (1955) gave no description of their sampling methods, but their samples were collected with seines (Dalquest pers. comm.).

Limited information is available for the Canadian River fish assemblage during the 1970s and 1980s. On 22 April 1972, F. B. Cross and party sampled one site downstream from Lake Meredith (KU14702-KU14710). During August 1983, the US Bureau of Reclamation and Texas Parks and Wildlife Department (unpublished data) sampled 35 sites on the Canadian River, from the New Mexico-Texas border to the upper reaches of Lake Meredith. We include here fish collections from all sites except the lowermost, which consisted mostly of lacustrine fishes.

In the 1990s, the Canadian River was sampled by Larson et al. (1991), the Texas Parks and Wildlife Department (1990), L. W. Reed Consultants, Inc. (1995), and by us. Larson et al. (1991) collected fish from seven sites in July 1990. Two of these sites were upstream and five were downstream from Lake Meredith. Larson et al. (1991) sampled shallow water (< 1 m) habitats with a 3.6-m x 1.8-m minnow seine with 0.32-mm mesh. In September 1990, the Texas Parks and Wildlife Department (1990) sampled two sites downstream from Lake Meredith. Fish were collected with duplicate three-minute hauls of a 6.1-m bag seine. In September 1995, L. W. Reed Consultants, Inc. (1995) sampled 17 sites on the Canadian River upstream from Lake Meredith. Their collections were made with triplicate hauls of a 6.1-m x 1.2-m bag seine with 6.4-mm mesh. Because of high flows in the river, the seine was rolled up to width of 2.4-3.0 m. Each seine haul covered a distance of 9.1-18.3 m and an area of 26-56 m^2. We sampled the Canadian River during September 1995 through January 1996. We collected fish at two downstream sites (Highway State 70 crossing, north of Pampa, Roberts County; US Highway 83 crossing, north of Canadian, Hemphill County) in October and November 1995, and from two upstream sites (US Highway 385 crossing, south of Tascosa, Oldham County; US Highway 287 crossing, north of Amarillo, Hutchinson County) from September 1995 through January 1996. Collections were made with a 3.6 x 1.5-m minnow seine with 6.4-mm mesh. We sampled each site for 30-45 minutes, sampling all available habitat types. Fish were preserved in 10% formalin until 100-200 specimens were collected.

Henceforth, we refer to sampling locations between Ute Reservoir and Lake Meredith as upstream sites, and those downstream from Lake Meredith as downstream sites (Figure1).

Historic discharge data were obtained from US Geological Survey (USGS) gauging stations located on the Canadian River at the US Highway 287 crossing, north of Amarillo, Texas (USGS gauge number 07227500), and at the State Highway 70 crossing in Canadian, Texas (USGS gauge number 07228000). The first site is located downstream from Ute Reservoir but just upstream from Lake Meredith; the second is downstream from the lake. A series of large floods occurred in the Canadian River in the early 1940s, so we used only those data collected since 1943 (inclusive). Therefore, our estimates of historic changes in river discharge may be conservative.

For each gauging station, we calculated mean discharge for periods before and after impoundment of Ute Reservoir and Lake Meredith. Thus, historic discharge in the Canadian River below Ute Reservoir (but upstream from Lake Meredith) was calculated for the period 1943-1962 and discharge downstream from Lake Meredith was calculated for 1943-1965. Post-impoundment discharge was estimated using data through 1996.

Reproduction of some Canadian River fishes is believed to be related to flood events (e.g., Moore 1944, Cross and Moss 1987). Therefore, we also determined the frequency of daily discharges that exceeded 14.2 m^3/s (500 cfs) and 28.3 m^3/s (1000 cfs) during the spawning season (May through August) in pre- and post-impoundment periods.

RESULTS

Twenty-seven species of fish, representing ten families, were collected from the Canadian River between 1954 and 1996 (Tables 1 and 2). Twenty-one species were collected from upstream sites, and 21 species were collected from sites downstream from Lake Meredith. In the earliest (1954-1955) collections from the Canadian River, the fish assemblage was fairly homogeneous across the Texas Panhandle. *Hybognathus placitus* and *N. girardi* dominated the assemblage, composing 90% of the fishes collected from upstream sites and 96% of the fishes from downstream sites. *Fundulus zebrinus* represented 5%, and *Lepomis cyanellus* 3%, of fishes captured from upstream sites. Although neither *F. zebrinus* nor *L. cyanellus* was collected from downstream sites, during 1954-1955 both were common in tributaries to the river in this area (Lewis and Dalquest 1955). Other species collectively represented less than 2% of the fish assemblage at all sites.

Since 1954-1955, fish assemblages in upstream and downstream areas of the Canadian River have diverged considerably. Upstream, *H. placitus* and *N. girardi* continued to dominate the assemblage; however, *H. placitus* decreased in relative abundance, composing only 7-48% of the assemblage (Table 1). *Notropis girardi* maintained its historic relative abundance, composing 18-47% of the assemblage. There has been a substantial increase in the relative abundance of *M. aestivalis*, from less than 1% in 1954-1955 to 12-24% in the 1990s. There was no evident change in the relative abundance of *P. gracilis* since the 1950s. Finally, although composing a small proportion of the assemblage, there has been an increase in the relative abundance of species (*Carpiodes carpio*, *Dorosoma cepedianum*, *Menidia beryllina*, *Morone chrysops*, and *Pomoxis annularis*) that likely occur in the river as upstream migrants from Lake Meredith.

The greatest changes in the fish assemblage of the Canadian River occurred downstream from Lake Meredith (Table 2). *Hybognathus placitus* and *N. girardi*, which composed 96% of the assemblage in 1954-1955, composed only 0.3% of the fish assemblage in 1995-1996. Neither *M. aestivalis* nor *P. gracilis* has been collected from this portion of the Canadian River since impoundment of Lake Meredith. *Cyprinella lutrensis* and *N. stramineus*, which occurred infrequently in the Canadian River in 1954-1955, have increased in abundance and composed 90% of the fish assemblage in 1995-1996.

Since 1943, mean annual discharge of the Canadian River downstream from Ute Reservoir has been variable, generally ranging between 5.7 and 14.2 m^3/s (Figure 2). Since 1962, the frequency of years characterized by high discharge has decreased noticeably. Mean discharge during 1943 through 1961 averaged 8 m^3/s but decreased 38% after impoundment to 5 m^3/s. Discharge has similarly decreased during the summer spawning season (May-August). From 1943 to 1961, flows in excess of 28.3 and 14.2 m^3/s occurred on 14%, and 24% of

Table 1. Relative abundance, and total number collected, of fishes captured in the Canadian River, Texas, downstream from Ute Reservoir between 1954 and 1990.

Scientific name	Common name	1954-55	1983	1990	1995-96
Ameiurus melas	Black bullhead	0.26			
Carpiodes carpio[a]	River carpsucker		0.34	0.19	0.29
Cyprinella lutrensis	Red shiner	0.18	35.70	14.07	9.24
Cyprinus carpio	Common carp		0.48		
Dorosoma cepedianum	Gizzard shad		0.58		0.52
Fundulus zebrinus	Plains killifish	5.39	11.50	2.25	3.60
Gambusia affinis	Western mosquitofish	0.31	2.13	0.19	2.66
Hybognathus placitus	Plains minnow	64.78	11.76	6.75	47.76
Ictalurus punctatus	Channel catfish	0.22	5.80	0.19	0.80
Lepomis cyanellus	Green sunfish	2.56	0.30		0.19
Lepomis macrochirus	Bluegill sunfish		0.09		
Macrhybopsis aestivalis	Speckled chub	0.09	3.78	24.39	12.43
Menidia beryllina	Inland silverside				0.06
Morone chrysops	White bass				0.04
Notropis girardi	Arkansas River shiner	25.21	25.04	46.53	18.04
Notropis stramineus	Sand shiner				2.01
Percina caprodes[b]	Logperch		0.03		
Pimephales promelas	Fathead minnow	0.28			1.82
Pimephales vigilax	Bullhead minnow		2.32	0.94	0.06
Platygobio gracilis	Flathead chub	0.72		4.50	0.46
Pomoxis annularis	White crappie		0.06		
Total number collected		4566	3282	533	4772

[a]Misreported as freshwater drum (*Aplodinodus grunniens*) by L. W. Reed Consultants, Inc. (1995).

[b]Probably represents misidentified specimens of *P. macrolepida*, which has been collected from Ute Reservoir (Sublette et al. 1990).

days, respectively. After impoundment of Ute Reservoir, flows exceeding 28.3 (7% of days) and 14.2 m^3/s (15%) were reduced in frequency by approximately 50%.

Mean annual discharge of the Canadian River downstream from Lake Meredith has been less than 25.5 m^3/s since 1943 (Figure 2). Since impoundment of Lake Meredith there has been a complete lack of high discharge years. Mean annual discharge decreased 76%, from 9.9 m^3/s during 1943-1965 to 2.4 m^3/s, since 1966. Mean daily discharge during the summer spawning season decreased more dramatically. From 1943 to 1965, flows in excess of 28.3 and 14.2 m^3/s occurred on 15%, and 22% of days, respectively. After impoundment of Lake Meredith, flows exceeding 28.3 m^3/s (2% of days) and 14.2 m^3/s (3%) were reduced in frequency by approximately 87%.

Table 2. Relative abundance, and total number collected, of fishes captured in the Canadian River, Texas, downstream from Lake Meredith between 1954 and 1990.

Scientific name	Common name	1954-55	1972	1990	1995-96
Ameiurus melas	Black bullhead	0.22			
Cyprinella lutrensis	Red shiner	0.15	38.94	11.47	45.00
Cyprinodon rubrofluviatilis	Red River pupfish		0.15	14.08	1.46
Cyprinus carpio	Common carp			0.02	
Fundulus zebrinus	Plains killifish	0.39	7.88	23.39	0.68
Gambusia affinis	Western mosquitofish	1.09	4.24	2.41	4.08
Hybognathus placitus	Plains minnow	74.43	13.94	28.15	0.10
Ictalurus punctatus	Channel catfish	0.01			
Lepomis cyanellus	Green sunfish	0.15	1.06		0.19
Lepomis macrochirus	Bluegill sunfish	0.04		0.02	
Lepomis microlophus	Redear sunfish	0.31			
Macrhybopsis aestivalis	Speckled chub	0.05			
Micropterus salmoides	Largemouth bass	0.03		0.55	
Notemigonus crysoleucas	Golden shiner	0.01			
Notropis atherinoides	Emerald shiner			1.66	0.68
Notropis girardi	Arkansas River shiner	21.57	32.27	7.45	0.20
Notropis stramineus	Sand shiner		0.76	9.78	44.90
Phenacobius mirabilis	Suckermouth minnow			1.03	0.29
Pimephales promelas	Fathead minnow	0.03	0.76		2.43
Pimephales vigilax	Bullhead minnow				0.19
Platygobio gracilis	Flathead chub	1.50			
Total number collected		9171	660	5063	1029

DISCUSSION

Changes in the fish assemblage of the Canadian River in Texas since impoundment of Ute Reservoir and Lake Meredith appear to be related to the degree that discharge has declined downstream from these reservoirs, especially during the spawning season. Mean annual discharge is 72% of the historic mean discharge downstream from Ute Reservoir and the fish assemblage is dominated by large-river species (*H. placitus*, *M. aestivalis*, *N. girardi*, and *P. gracilis*) that historically composed the majority of the assemblage. In contrast, mean annual discharge has declined to only 24% of the mean historic discharge downstream from Lake Meredith and the fish assemblage now is dominated by species (*C. lutrensis* and *N. stramineus*) that historically inhabited smaller tributary streams (Lewis and Dalquest 1955, Cross and Moss 1987).

Hybognathus placitus, *M. aestivalis*, *N. girardi*, and *P. gracilis* are members of a guild of prairie stream fishes that spawn nonadhesive, semibuoyant eggs (Platania and Altenbach 1998). Spawning is believed to occur in response to floods, which increase stream flows and keep the semibuoyant eggs afloat until hatching occurs (Moore 1944, Bottrell et al. 1964, Cross et al. 1983, Lehtinen and Layzer 1988, Taylor and Miller 1990). Newly-hatched fry are weak swimmers, so strong currents also are required to keep fry suspended so that they do not settle to the bottom and become buried (Moore 1944). The reduced frequency of large floods and their importance for reproduction by *H. placitus*, *M. aestivalis*, *N. girardi*, and *P. gracilis* probably explains the absence of these species in the Canadian River downstream from Lake Meredith.

The occurrence of high flow events during the spawning season does not seem to be the only factor required for successful reproduction by members of the reproductive guild described by Platania and Altenbach (1998). Depending on channel morphology and current velocity, Platania and Altenbach (1998) estimated that eggs could be transported 72-144 km before hatching and, depending on developmental rates, fry could be transported for distances as great as 216 km. These estimates suggest that a substantial length of unimpounded river (200-300 km) may be required for successful reproduction, although a population of *M. aestivalis* occurs in an 89-km reach of the upper Pecos River, New Mexico (Platania and Altenbach 1998). The Canadian River flows approximately 218 km from the tailwaters of Ute Reservoir to the upper reaches of Lake Meredith. This distance may well approximate the minimum length of river necessary for maintenance of the large-river species, *H. placitus*, *M. aestivalis*, *N. girardi*, and *P. gracilis*.

Downstream from Lake Meredith, the Canadian River has undergone dramatic changes that have affected the fish assemblage. Lake Meredith has never discharged, consequently the Canadian River downstream is small (≤ 3 m wide) and fed by seepage from Sanford Dam. The river gains volume further downstream from springs, tributaries, and municipal and industrial effluents. Just west of the Oklahoma-Texas border, 121 km downstream, the Canadian River contains only 24% of its historic volume. This decreased volume has, in turn, affected channel morphology. Historically, the river had a wide braided-channel, but it now has a narrow channel without braids (Friedman et al. 1998).

These changes in river volume and channel morphology in the Canadian River downstream from Lake Meredith are associated with an almost complete replacement of large-river species, which historically dominated the assemblage, by species that are characteristic of small tributary streams in the drainage. The current abundance of tributary species may result from changes in competitive and predatory interactions (e.g., Cross and Moss 1987, Pflieger and Grace 1987) that favor these species over those that naturally occurred in the river mainstem. Instead, we believe that altered hydrologic conditions (reduced discharge, fewer and less voluminous floods) have allowed *C. lutrensis*, *N. stramineus*, and other tributary species to colonize the river (Moyle and Light 1996, Wilde and Bonner 2000). Historically, these tributary species were uncommon in the Canadian River (Lewis and Dalquest 1955), possibly because they are susceptible to being displaced by strong currents (Summerfelt and Minckley 1969, Pflieger and Grace 1987, Kelsch 1994). Indeed, Lewis and Dalquest (1955) suggested that the presence of these species in the Canadian River was the result of their being washed in from tributary streams during floods.

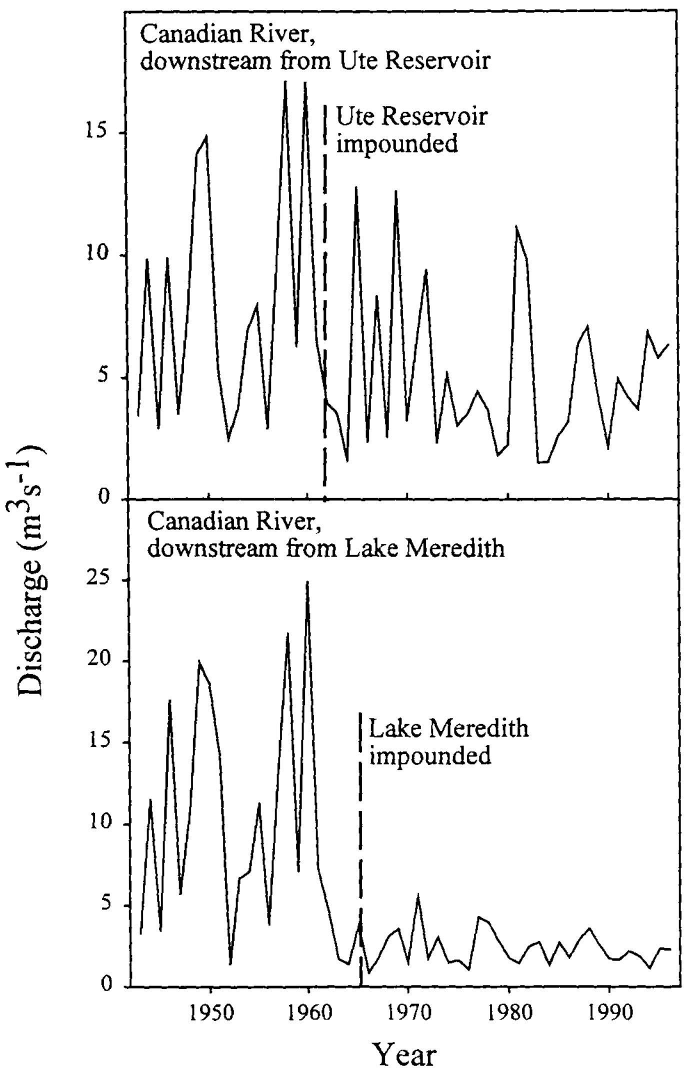

Figure 2. Mean annual discharge (m^3/s) in the Canadian River, Texas, upstream and downstream from Lake Meredith, during 1943-1996.

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LITERATURE CITED

Bain, M. B., J. T. Finn, and H. E. Booke. 1988. Streamflow regulation and fish community structure. Ecology 69:382-392.

Baxter, R. M. 1977. Environmental effects of dams and impoundments. Annual Reviews of Ecology and Systematics 8:255-283.

Bottrell, C. E., R. H. Ingersol, and R. W. Jones. 1964. Notes on the embryology, early development, and behavior of *Hybopsis aestivalis tetranemus* (Gilbert). Transactions of the American Microscopical Society 83:391-399.

Cross, F. B., and R. E. Moss. 1987. Historic changes in fish communities and aquatic habitats in plains streams of Kansas, pp. 155-165 *In* W. J. Matthews and D. C. Heins, editors. Community and evolutionary ecology of North American stream fishes. University of Oklahoma Press, Norman.

Cross, F. B., O. T. Gorman, and S. G. Haslouer. 1983. The Red River shiner, *Notropis bairdi*, in Kansas with notes on depletion of its Arkansas River cognate, *Notropis girardi*. Transactions of the Kansas Academy of Science 7:222-226.

Dolliver, P. N. 1984. Cenozoic evolution of the Canadian River Basin. Baylor Geological Studies Bulletin No. 42. Waco, Texas.

Friedman. J. M., W. R. Osterkamp, M. L. Scott, and G. T. Auble. 1998. Downstream effects of dams on channel geometry and bottomland vegetation: regional patterns in the Great Plains. Wetlands 18:619-633.

Holden, P. B. 1979. Ecology of riverine fishes in regulated stream systems with emphasis on the Colorado River, pp. 57-74 *In* J. V. Ward and J. A. Stanford, editors. The ecology of regulated streams. Plenum Press, New York.

Kelsch, S. W. 1994. Lotic fish-community structure following transition from severe drought to high discharge. Journal of Freshwater Ecology 9: 331-341.

L. W. Reed Consultants, Inc. 1995. Summary of threatened and endangered species surveys completed for the D. S. E. El Paso pipeline project. L. W. Reed Consultants, Inc., Fort Collins, Colorado.

Larson, R. D., A. A. Echelle, and A. V. Zale. 1991. Life history and distribution of the Arkansas River shiner in Oklahoma. Final Report Federal Aid Project E-8. Oklahoma Department of Wildlife Conservation, Oklahoma City.

Lehtinen, S. F., and J. B. Layzer. 1988. Reproductive cycle of the plains minnow, *Hybognathus placitus* (Cyprinidae), in the Cimarron River, Oklahoma. Southwestern Naturalist 33:27-33.

Lewis, L. D., and W. W. Dalquest. 1955. Final Report Federal Aid Project F-7-R-2. Texas Game, Fish and Oyster Commission (now Texas Parks and Wildlife Department), Austin.

Limbird, R. L. 1993. The Arkansas River- a changing river, pp. 282-294 *In* L. W. Hesse, C. B. Stalnaker, N. G. Benson, and J. R. Zuboy, editors. Restoration planning for the rivers of the Mississippi River ecosystem. National Biological Survey, Washington, DC.

Matthews, W. J. 1987. Physicochemical tolerance and selectivity of stream fishes as related to their geographic ranges and local distributions, pp. 111-120 *In* W. J. Matthews and D. C. Heins, editors. Community and evolutionary ecology of North American stream fishes. University of Oklahoma Press, Norman.

Moore, G. A. 1944. Notes on the early life history of *Notropis girardi*. Copeia 1944:209-214.

Moyle, P. B., and T. Light. 1996. Fish invasions in California: do abiotic factors determine success? Ecology 77:1666-1670.

Patton, T. M., and W. A. Hubert. 1993. Reservoirs on a Great Plains stream affect downstream habitat and fish assemblages. Journal of Freshwater Ecology 8:279-286.

Pflieger, W. L., and T. B. Grace. 1987. Changes in the fish fauna of the lower Missouri River, 1940-1983, pp. 166-177 *In* W. J. Matthews and D. C. Heins, editors. Community and evolutionary ecology of North American stream fishes. University of Oklahoma Press, Norman.

Pigg, J. 1991. Decreasing distribution and current status of the Arkansas River shiner, *Notropis girardi*, in the rivers of Oklahoma and Kansas. Proceedings of the Oklahoma Academy of Science 71:5-15.

Platania, S. P., and C. S. Altenbach. 1998. Reproductive strategies and egg types of seven Rio Grande Basin cyprinids. Copeia 1998:559-569.

Stanford, J. A. & J. V. Ward. 1979. Stream regulation in North America, pp. 215-236 *In* J. V. Ward and J. A. Stanford, editors. The ecology of regulated streams. Plenum Press, New York.

Sublette, J. E., M. D. Hatch, and M. Sublette. 1990. The fishes of New Mexico. University of New Mexico, Albuquerque.

Summerfelt, R. C., and C. O. Minckley. 1969. Aspects of the life history of the sand shiner, *Notropis stramineus* (Cope), in the Smoky Hill River, Kansas. Transactions of the American Fisheries Society 98:444-453.

Taylor, C. M., and R. J. Miller. 1990. Reproduction ecology and population structure of the plains minnow, *Hybognathus placitus* (Pisces: Cyprinidae), in central Oklahoma. American Midland Naturalist 123:32-39.

Texas Almanac. 1995. Dallas Morning News, Inc. Dallas, Texas.

Texas Parks and Wildlife Department. 1990. Commercial minnow harvester study. Texas Parks and Wildlife Department, Austin.

Wilde, G. R., and T. H. Bonner. 2000. First records of the suckermouth minnow *Phenacobius mirabilis* from the Canadian River, Texas. Texas Journal of Science 52:71-74.

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