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Source: Cathryn A. Hoyt and John Karges (editors) 2014. *Proceedings of the Sixth Symposium on the Natural Resources of the Chihuahuan Desert Region* October 14–17, 2004. pp. 396–408.

Published by: The Chihuahuan Desert Research Institute, Fort Davis, TX.
Submitted in 2004

Recommended citation: Garrett, G.P., and R.J. Edwards. 2014. Changes in fish populations in the Lower Canyons of the Rio Grande. In: C.A. Hoyt & J. Karges (editors). *Proceedings of the Sixth Symposium on the Natural Resources of the Chihuahuan Desert Region. October 14–17*. Chihuahuan Desert Research Institute, Fort Davis, TX. pp. 396–408. <http://cdri.org/publications/proceedings-of-the-symposium-on-the-natural-resources-of-the-chihuahuan-desert-region/>

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Changes in Fish Populations in the Lower Canyons of the Rio Grande

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ABSTRACT—The Lower Canyons of the Rio Grande suffer from environmental degradation that has negatively impacted native fish populations and their distributions. *Macrhybopsis aestivalis* (speckled chub), *Notropis jemezianus* (Rio Grande shiner), *Rhinichthys cataractae* (longnose dace) and *Cycleptus elongatus* (blue sucker) populations appear to have suffered recent declines. Although diminished water quantity is likely an important factor in these declines, related changes in channel morphology precipitated by massive stands of *Arundo donax* (giant reed) and *Tamarix* sp. (salt cedar) may also be responsible. These invasive exotics have essentially channelized the river, disrupted normal sediment distribution and reduced shallow, low-velocity habitats. Much of the Lower Canyons of the Rio Grande are devoid of sandy sediment and most riffles are now composed of gravel and cobble.

On 10 November 1978, a 315-km stretch of the Rio Grande was designated for inclusion as part of the nation's Wild and Scenic Rivers. This designation included 111 km of river along the boundary of Big Bend National Park starting above Mariscal Canyon at the border of Chihuahua and Coahuila, México and extending 204 km downstream from the park to the border of Terrell and Val Verde counties, Texas (PL 90-542; 16 U.S.C. 1271-1287). In the enabling legislation, this segment of the Rio Grande was characterized as having “remarkable scenic, recreational, geologic, fish and wildlife, historic or cultural values.” One of the original intents of the Wild and Scenic Rivers Act was to protect significant free-flowing rivers and their surrounding environments for the benefit and enjoyment of present and future generations. The 204-km portion of the river downstream from Big Bend National Park is known as “the Lower Canyons” and contains many of the most outstanding features found in the river. In 1998, President Clinton designated the Rio Grande as one of 14 American Heritage Rivers.

Within the Lower Canyons, the river varies in width from approximately 20 to 70 m with swift moving rapids interspersed with slower, deeper pools. The river is often constrained between high canyon walls, some over 150 m high, alternating with more

open *vegas* typical of the Chihuahuan Desert. The streambed substrates range from silt to cobbles and boulders. Several spring seeps, some with relatively significant discharge, enter the river in the Lower Canyons. The Rio Grande is perennial throughout the Wild and Scenic River portion. Major flow reductions occurred during the severe drought in the 1950s and in 2003 when portions of the river near Solis ceased to flow (Raymond Skiles, Big Bend National Park, in litt.). Typically, there is a seasonal (August through October) peak in flow due to large storm events. The peak duration is now unnaturally short due to water diversions and dams on the Río Conchos.

Fishes of the Lower Canyons have not been as intensively studied as elsewhere in the drainage due, in part, to the difficulty in accessing the region. Reports by Girard (1859), Evermann and Kendall (1894), Hubbs (1940), and Miller (1977) documented fishes of the region, but did not specifically include the Lower Canyons. Hubbs et al. (1977) was the first to provide detailed data on fishes inhabiting the Lower Canyons. Recent studies include more comprehensive surveys (Edwards et al. 2002). The purpose of this paper is to provide an inventory of the fishes present in the Lower Canyons and to relate changes observed in fish populations to changes in the riverine habitat.

METHODS—The area of study in the Lower Canyons (Fig. 1) was accessed by canoe and encompassed the river from the mouth of Maravillas Canyon (N29.56138889 W-102.7777778) to Dryden Crossing (N29.80888889 W-102.1480556). Sampling locations were fairly evenly spaced within this 114-km stretch, but specific locations were largely determined by accessibility. Stream flows during our study period ranged from approximately 7 m³/s to nearly 19 m³/s toward the end of our collections, due to rainfall further upstream in the basin.

Forty-two collections at 21 sites were made from 6 through 11 June 2004. Upstream, downstream and across-stream seining was employed and the length of time at each location was recorded (typically 20 to 30 min). The majority of samples were obtained using small mesh seines (3 to 6-m long with 2 to 6-mm mesh), with some supplement by gill and hoop nets. All habitat types at each station were thoroughly sampled (typically 10 to 50-m stream stretches) in relative proportion to their occurrence. This method was employed to obtain a representative sample of the relative abundance of fish species present at each site. Comparisons of cyprinid relative abundance were derived from seine collection data only. Values for relative abundance comparisons among the cyprinids do not include other species.

Most fishes collected were preserved in the field and identified and counted in the laboratory. A few of the larger fishes captured were counted and returned to the

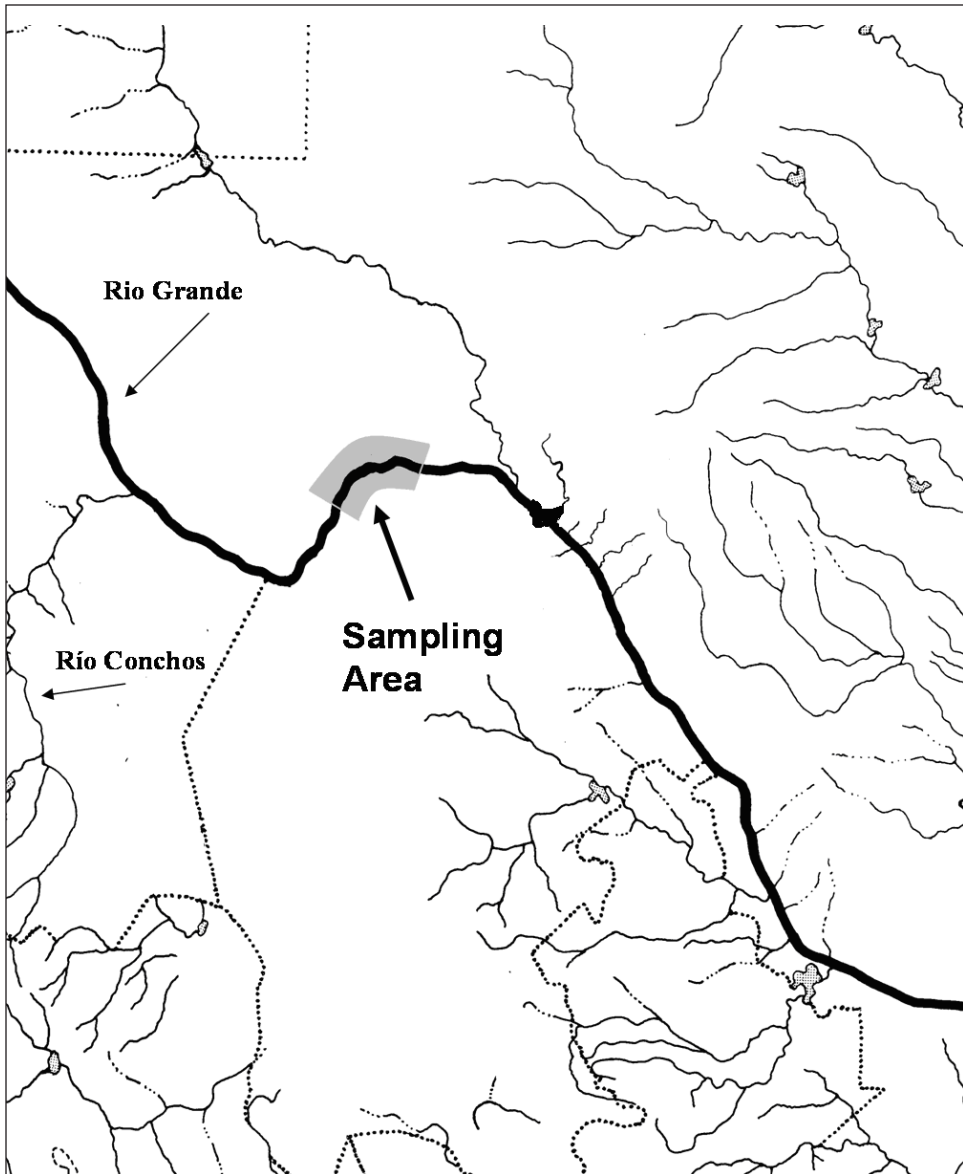


FIG. 1—Map of the Lower Canyons of the Rio Grande showing the area sampled.

river. Retained specimens were deposited in the Texas Natural History Collections at the University of Texas, Austin.

Comparative historical relative abundances of fishes were taken from three sources: a series of nine collections reported by Hubbs et al. (1977) taken 3 through 7 April 1977, a series of 4 collections taken 22 through 24 February 1990 reported by Platania (1990), and 32 collections taken 6 through 8 January 1992 and reported by Edwards

et al. (2002). Each effort used seines for the collections and in each, the objective was to obtain fishes in the proportion in which they occurred.

Changes in river channel morphology were determined subjectively from a visual inspection of photographs from our 1992 collections and from recollections of persons with detailed knowledge spanning several decades on the Lower Canyons.

RESULTS—Collections in 2004 revealed several changes in the fish assemblage of the Lower Canyons relative to previous studies (Table 1). Twenty species were taken in this study. The most abundant species were *Lepisosteus osseus* (longnose gar), *Cyprinella lutrensis* (red shiner), *Notropis braytoni* (Tamaulipas shiner), *Carpionodes carpio* (river carpsucker), *Astyanax mexicanus* (Mexican tetra), *Ictalurus furcatus* (blue catfish) and *Gambusia affinis* (western mosquitofish). Two species (*C. lutrensis* and *N. braytoni*) accounted for 75% of all fishes captured. Species which were represented by at least five individuals were *Dorosoma cepedianum* (gizzard shad), *Cyprinus carpio* (common carp), *Rhinichthys catarractae* (longnose dace), *Ictiobus bubalus* (smallmouth buffalo), *Ictalurus lupus* (headwater catfish), *Pylodictis olivaris* (flathead catfish) and *Lepomis macrochirus* (bluegill). The other species were represented only by one or at most two individuals in our 2004 collections.

Seven species taken in earlier studies were not encountered in our samples (Table 1): *Notropis chihuahua* (Chihuahua shiner), *N. jemezianus* (Rio Grande shiner), *Pimephales promelas* (fathead minnow), *Cycleptus elongatus* (blue sucker), *Menidia beryllina* (inland silverside), *Morone chrysops* (white bass) and *Micropterus salmoides* (largemouth bass).

Relative abundance of some species appeared to differ significantly between the present study and previous collections (Table 1). *Cycleptus elongatus* has suffered a substantial decrease since 1977 when it was the third-most abundant fish in collections from the Lower Canyons region. The 1977 collections were during the late spring/early summer and all specimens were young of the year.

Other declines were found, especially among some of the indigenous minnows in this reach. *Macrhybopsis aestivalis* (speckled chub), *Notropis jemezianus*, and *Rhinichthys catarractae* were much less abundant in our present study than during previous collections (Fig. 2 and 3). Although some of the differences depicted in the figures may be due to samples taken at different times of the year, these are all short-lived, high-fecundity species with similar spawning times, thus seasonal relative abundance among these species would be expected to vary in similar ways. Most importantly, the 1977 and 2004 collections were taken at similar times (May 1977 and June 2004) and best illustrate the magnitude of change.

TABLE 1—Relative abundance (%) of fishes in the Lower Canyons of the Rio Grande. Data sources are Hubbs et al., 1977 (Apr-77); Platania, 1990 (Feb-90); Edwards et al., 2002 (Jan-92) and this study (Jun-04).

Species	Common Name	Relative Abundance			
		Apr-77	Feb-90	Jan-92	Jun-04
<i>Lepisosteus osseus</i>	longnose gar	0.23		0.16	1.02
<i>Dorosoma cepedianum</i>	gizzard shad	2.76		0.47	0.23
<i>Cyprinella lutrensis</i>	red shiner	7.73	59.27	13.40	16.23
<i>Cyprinus carpio</i>	common carp	0.18			0.20
<i>Dionda episcopa</i>	roundnose minnow				0.03
<i>Macrhybopsis aestivalis</i>	speckled chub	4.14		8.26	0.03
<i>Notropis braytoni</i>	Tamaulipas shiner	3.17	0.23	7.17	59.00
<i>Notropis chihuabua</i>	Chihuahua shiner	0.05			
<i>Notropis jemezianus</i>	Rio Grande shiner	5.38	3.66	6.39	
<i>Pimephales promelas</i>	fathead minnow	0.09	0.23		
<i>Rhinichthys cataractae</i>	longnose dace	64.31	19.91	33.49	0.16
<i>Carpiodes carpio</i>	river carpsucker	0.55	9.15	3.74	9.79
<i>Cycoreptes elongatus</i>	blue sucker	6.72			
<i>Ictiobus bubalus</i>	smallmouth buffalo	0.05		1.40	0.43
<i>Astyanax mexicanus</i>	Mexican tetra	0.05		0.47	6.60
<i>Ictalurus furcatus</i>	blue catfish	2.30		8.26	2.14
<i>Ictalurus lupus</i>	headwater catfish	0.78		1.09	0.43
<i>Pylodictis olivaris</i>	flathead catfish	0.32	0.46	2.18	0.43
<i>Fundulus zebrinus</i>	plains killifish	0.09			0.07
<i>Gambusia affinis</i>	western mosquitofish	0.69	3.66	2.49	2.89
<i>Menidia beryllina</i>	inland silverside	0.18	2.75	0.16	
<i>Morone chrysops</i>	white bass			0.31	
<i>Lepomis cyanellus</i>	green sunfish	0.05		9.35	0.03
<i>Lepomis macrochirus</i>	bluegill	0.09	0.69	0.93	0.23
<i>Lepomis megalotis</i>	longear sunfish				0.03
<i>Micropterus salmoides</i>	largemouth bass	0.09			
<i>Aplodinotus grunniens</i>	freshwater drum			0.31	0.03
Number of specimens		2,174	437	642	3,044

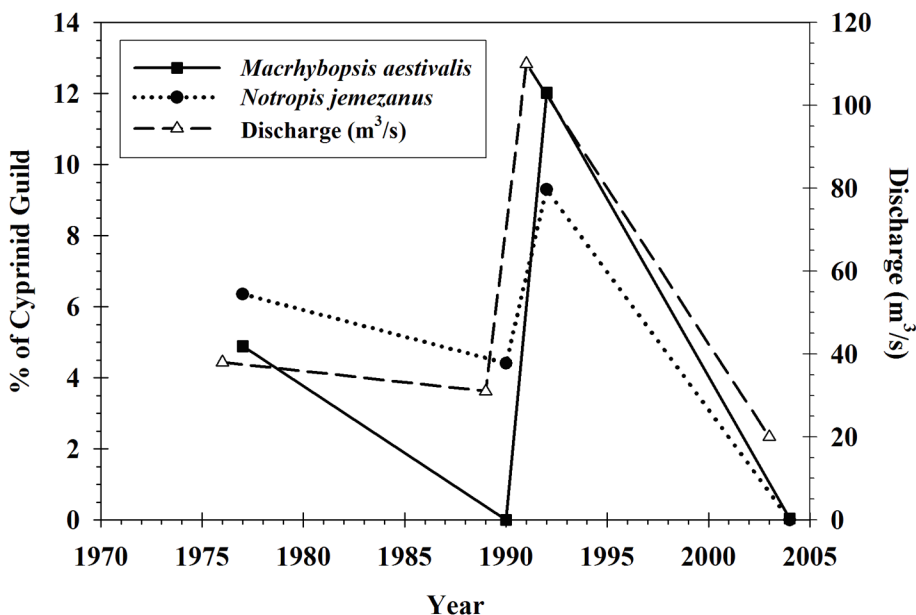


FIG. 2.—Relative abundance of *Macrhybopsis aestivalis* and *Notropis jemezanus* as a percent of the cyprinid guild (*Cyprinella lutrensis*, *Macrhybopsis aestivalis*, *Notropis braytoni*, *Notropis jemezanus* and *Rhinichthys cataractae*) in the Lower Canyons of the Rio Grande. Shown also are Rio Grande flows (m³/s), measured at the USGS gauge near Langtry, Texas. Flow values shown are the average annual flow for the previous year.

USGS and IBWC flow readings from three representative locations (Presidio, Castolon, and Langtry) reveal a general decline in flow in the Rio Grande (Fig. 4) during their periods of record. Although all three stations exhibit similar hydrological patterns, the Langtry stream gauge is probably most appropriate for relating to fish abundance changes because it incorporates the spring inflows in the Big Bend and Lower Canyons reaches. Relative abundance trends of *Macrhybopsis aestivalis* and *Notropis jemezanus* appear to mirror the trend in the previous year's flow pattern of the Rio Grande (Fig. 2). Conversely, *Cyprinella lutrensis* and *Notropis braytoni* seem to have fared well under these conditions (Fig. 3). In addition, the 2004 collections revealed a large increase in *Astyanax mexicanus* in the main channel (Table 1).

DISCUSSION— Increases in the abundance of *Cyprinella lutrensis*, *Notropis braytoni*, and *Astyanax mexicanus* as well as concurrent decreases in relative abundance of *Macrhybopsis aestivalis*, *Notropis jemezanus*, *Rhinichthys cataractae*, and *Cycleptus elongatus*, appear related to drought, decreased flow, and the concomitant effects on stream and riparian habitat

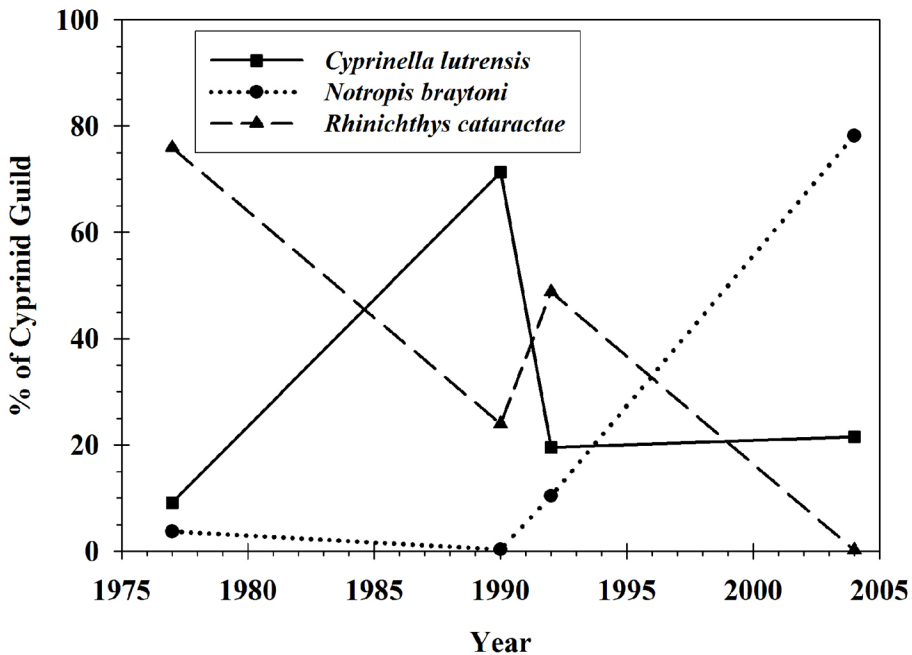


FIG. 3—Relative abundance of *Cyprinella lutrensis*, *Notropis braytoni* and *Rhinichthys cataractae* as a percent of the cyprinid guild (*Cyprinella lutrensis*, *Macrhybopsis aestivalis*, *Notropis braytoni*, *Notropis jemezianus* and *Rhinichthys cataractae*) in the Lower Canyons of the Rio Grande.

(Edwards et al. 2002; Edwards et al. 2004). Reduced abundance of *C. elongatus* in Texas has been attributed to pollution and reduced water flows (Edwards et al. 2004). This is a large-river fish that prefers strong current in main channels of medium to large rivers (Page and Burr 1991). It is widely distributed in the United States, but has suffered population declines in some locations. The Rio Grande population of *C. elongatus* is of particular interest because it appears to be a distinct evolutionary lineage (Buth and Mayden 2001).

Macrhybopsis aestivalis and *Notropis jemezianus* seem to be particularly susceptible to flow modifications and changes in channel morphology. They are typically associated with sandy, small-gravel riffles and backwaters. These fishes are pelagic spawners, producing nonadhesive, semibuoyant eggs that drift considerable distances downstream (Platania and Altenbach 1998).

Factors contributing to the decrease in *Rhinichthys cataractae* are not readily apparent. This species produces benthic, adhesive eggs and has benthic larvae, similar to *Cyprinella lutrensis* and *Notropis braytoni*. However, fry prefer quiet, shallow stream margins (Gibbons and Gee 1972) and a reduction in this habitat could have a detrimental impact on population size.

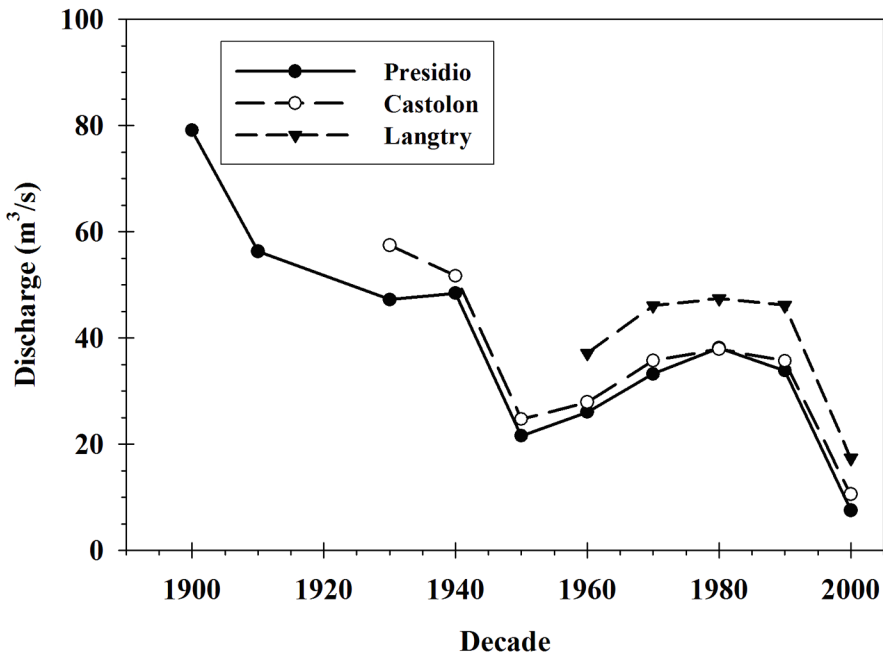


FIG. 4—Mean flow (by decade) in cubic meters per second (m^3/s) at three USGS Rio Grande gauging stations for their period of record. The Presidio station is below the confluence of the Río Conchos, Castolon is in Big Bend National Park at Johnson Ranch, and Langtry is below the Wild and Scenic River portion of the Rio Grande near Langtry, Texas.

The decrease in these species, as well as the prior extirpation of *Hybognathus amarus* (Rio Grande silvery minnow) and extinction of two other minnows, *Notropis simus simus* (Rio Grande bluntnose shiner) and *N. orca* (phantom shiner), all of which once inhabited the Lower Canyons region, remains of great concern. The Rio Grande from Presidio downstream through the Lower Canyons has been identified as one of the primary potential reintroduction sites for *H. amarus*, which is critically endangered and currently restricted to the mainstem Rio Grande around Albuquerque, New Mexico (U.S. Fish and Wildlife Service 1999).

Factors related to the decrease in some species may also be responsible for relative increases in others. Both *Cyprinella lutrensis* and *Notropis braytoni* are tolerant of turbid conditions and favor river channels. *Cyprinella lutrensis*, in particular, is known to be tolerant of harsh conditions and is typically found in high relative abundance under those circumstances (Cross and Collins 1975; Mayden 1989; Matthews et al. 2001). Their reproductive habits of producing demersal, adhesive eggs may also be an advantage in this situation. Although the life history requirements of *N. braytoni* are not dependent

on tributaries, they are seldom found far from creek mouths in the Rio Grande (Hubbs et al. 1977). Recent reduced flow may have transformed mainstem habitats, as more water in this reach would be from local spring flows. Whether this or other factors have contributed to the large increase in *N. braytoni* in 2004 is unknown and requires further study.

Astyanax mexicanus often occurs in headwaters and creeks with stenothermal waters (Edwards 1977; Sublette et al. 1990). In the Rio Grande it is most commonly found in tributary creeks (Hubbs et al. 1977). As with *Notropis braytoni*, its preference for spring-influenced waters may be partially responsible for this occurrence.

Mean flow of the Rio Grande in the Lower Canyons and the adjacent upstream area varies from 39.7 to 41.7 m³/s. The only gauge (from the Presidio gauging station downstream) which has not registered a no-flow condition is Langtry which recorded 2.7 m³/s in October 2000. However, the period of record for this gauge began after the 1950s drought. When daily average flow of gauges downstream from Presidio are summarized by decade, it becomes apparent that average flows since January 2000 have been far less than historic averages. The vast majority of the water in the Rio Grande in the Lower Canyons is derived from the Río Conchos in México. Because flow in the Rio Grande below Presidio is dependent upon the Río Conchos discharge, international cooperation between the U.S. and México is necessary to maintain perennial flow in the Rio Grande in the Lower Canyons.

Habitat changes throughout this segment of the river were notable, especially modification of the river channel due to establishment of dense stands of *Arundo donax* (giant reed). Although *A. donax* and *Tamarix* (salt cedar) have been in this region for decades, encroachment and concomitant negative effects have increased over time. Far more large gravel and rocky substrates, especially in riffle areas were noted in our 2004 visit than in 1992. Increase in *A. donax* coverage has also limited the number of available campsites in the Lower Canyons (Marcos Paredes, River Ranger, pers. comm.; Louis F. Aulbach, pers. comm.). Periodic flooding that occurred with greater regularity prior to the mid-1980s appeared to help regulate the dominance of *A. donax* and *Tamarix* and allowed the formation of a greater number of open gravel and sand bars. Since then, *A. donax* appears to be the dominant riparian vegetation in much of the Lower Canyons. In fact, large expanses are now composed almost entirely of stands of *A. donax*. This may be due, in part, to lack of scouring flows brought on by drought and upstream water management (Schmidt et al. 2003). Stand densities may now be so great that they can not be controlled by flood events. These stands appear to have effectively channelized the Lower Canyons and the resulting constricted flow

has reduced shallow, backwater habitat and changed bottom sediments from a mixture of sand and gravels to one of primarily larger gravels and cobble. The effect of the dense stands has also stabilized the riverbanks, thus preventing natural sediments and sand to be available for habitat within the river itself. These changes in river morphology must be considered as potential factors affecting the abundance of the fishes in this region.

There are also issues of degraded water quality in this portion of the Rio Grande. In the U.S. Water Quality Segment 2306 (Rio Grande from Presidio to Amistad Reservoir), primary water quality concerns include high bacterial levels, that sometimes exceed the criterion established to assure the safety of contact recreation (International Boundary and Water Commission 2003). Previous assessments of water quality (Blackstun et al. 1998) cited under-treated sewage from Presidio/Ojinaga and local border villages, livestock grazing in riparian areas, agricultural runoff, mining activities, and atmospheric deposition as factors affecting the Rio Grande between Presidio and Amistad Reservoir. Presence of toxic contaminants and elevated densities of fecal coliform bacteria have also been reported in water quality data of the Texas Natural Resource Conservation Commission (TNRCC), U.S. Section of the IBWC, and the U.S. Geological Survey (USGS) (Texas Natural Resource Conservation Commission 1994a).

The TNRCC (now Texas Commission on Environmental Quality) assessed available data and identified arsenic, cadmium, chromium, copper, lead, mercury, nitrogen, phosphorus, selenium, silver, zinc, DDD, DDE, DDT, dieldrin, endrin, hexachlorobenzene, PCBs, and total PAHs as constituents of concern in the area (Texas Water Commission 1992a, 1992b; Texas Natural Resource Conservation Commission 1994a, 1994b, 1994c). Despite the presence of these constituents, the TNRCC designated the Rio Grande from Presidio to Amistad Reservoir (TNRCC Segment 2306) suitable for public water supply, contact recreation, and high-quality, aquatic-habitat protection (Texas Natural Resources Conservation Commission 1995).

Substantial water and riparian habitat issues need to be addressed in order to conserve the native fish communities of the Lower Canyons region. An *Arundo/Tamarix* control program could enhance the survival potential of the unique aquatic elements in the Lower Canyons region. Concurrent efforts to ensure the presence of sufficient flow and a discharge that mimics the natural hydrological regime would be vital to such a program.

Many people helped make field collections in the Lower Canyons of the Rio Grande successful. We especially thank Marcos Paredes, Michael Ryan, Jeffery Bennett, Stephen McAllister, Sharon Collyer, and Jessica Erickson from Big Bend National Park for their help in the field as well as many of the Park volunteers who helped with logistical considerations. We also thank Aimee Roberson, Jason Remshardt, John Branstetter, Mike Buntjer, Rawls Williams, and Nathan Allan of the U.S. Fish and Wildlife Service for their able assistance in the field or additional logistical support. Partial funding provided by U.S. Fish and Wildlife Service Cooperative Agreement FWS# 1448-20181-02-J829 to RJE. Finally, we appreciate the valuable insight on long-term changes in the Lower Canyons provided during extensive discussions with Marcos Paredes, Louis F. Aulbach, Michael Ryan, and Raymond Skiles.

LITERATURE CITED

- BLACKSTUN, D., L. WOOSLEY, AND M. FLORA. 1998. Water resources issues in the Rio Grande—Río Conchos to Amistad Reservoir subarea. U.S. Department of the Interior. Field Coordinating Committee, Fact Sheet 3, April 1998
- BUTH, D.G., AND R.L. MAYDEN. 2001. Allozymic and isozymic evidence for polytypy in the North American catostomid genus *Cycleptus*. *Copeia* 2001:899–906.
- CROSS, F.B., AND J.T. COLLINS. 1975. *Fishes in Kansas*. University of Kansas Museum of Natural History and State Biological Survey, Public Education Series 3, University of Kansas, Lawrence.
- EDWARDS, R.J. 1977. Seasonal migrations of *Astyanax mexicanus* as an adaptation to novel environments. *Copeia* 1977:770–771.
- EDWARDS, R.J., G.P. GARRETT, AND N.L. ALLAN. 2004. Aquifer-dependent fishes of the Edwards Plateau region. In: R.E. Mace, E.S. Angle, W. F. Mullican, III, editors. *Aquifers of the Edwards Plateau*. Report 360, Texas Water Development Board, Austin, Texas. Proceedings of Aquifers of the Edwards Plateau Symposium, February 2004, San Angelo, Texas. Chapter 13. Pages 253–267.
- EDWARDS, R.J., G.P. GARRETT, AND E. MARSH-MATTHEWS. 2002. Conservation and status of the fish communities inhabiting the Río Conchos Basin and Middle Rio Grande, México and U.S.A. *Reviews in Fish Biology and Fisheries* 12:119–132.
- EVERMANN, B.W., AND W.C. KENDALL. 1894. The fishes of Texas and the Rio Grande Basin, considered chiefly with reference to their geographic distribution. Bulletin of the U.S. Fish Commission, Article 3:57–126, plates X to L.
- GIBBONS, J.R.H. AND J.H. GEE. 1972. Ecological segregation between longnose and blacknose dace (Genus *Rhinichthys*) in the Mink River, Manitoba. *Journal of the Fisheries Research Board of Canada* 29:1245–1252.
- GIRARD, C.F. 1859. Ichthyology of the boundary. In: *United States and Mexican Boundary Survey Under the Order of Lieut. Col. W.H. Emory, Major First Cavalry and United States Commissioner*. U.S. and Mexican Boundary Survey Report 2:1–85.

- HUBBS, C.L. 1940. Fishes from the Big Bend region of Texas. *Transactions of the Texas Academy of Science* 23:3–12.
- HUBBS, C., R.R. MILLER, R.J. EDWARDS, K.W. THOMPSON, E. MARSH, G.P. GARRETT, G. L. POWELL, D.J. MORRIS, AND R.W. ZERR. 1977. Fishes inhabiting the Rio Grande, Texas-Mexico, between El Paso and the Pecos confluence. In: R. Roy Johnson and Dale A. Jones, editors. *Importance, Preservation and Management of Riparian Habitat: A symposium*. USDA Forest Service, General Tech. Report, RM-43. Pages 91–97.
- INTERNATIONAL BOUNDARY AND WATER COMMISSION. 2003. Regional Assessment of Water Quality in the Rio Grande Basin, Texas Clean Rivers Program, United States Section, International Boundary and Water Commission.
- MATTHEWS, W.J., K.B. GIDO, AND E. MARSH-MATTHEWS. 2001. Density-dependent overwinter survival and growth of red shiners from a southwestern river. *Transactions of the American Fisheries Society* 130:478–488.
- MAYDEN, R.L. 1989. Phylogenetic studies of North American minnows, with emphasis on the genus *Cyprinella* (Teleostei: Cypriniformes). *University of Kansas Museum of Natural History Miscellaneous Publication* 80:1–189.
- MILLER, R.R. 1977. Composition and derivation of the native fish fauna of the Chihuahuan Desert Region. *Transactions of the Symposium on the Biological Resources of the Chihuahuan Desert Region, United States and Mexico*. USDI, NPS, Transactions and Proceedings Series 3:365–382.
- PAGE, L.M., AND B.M. BURR. 1991. *A field guide to freshwater fishes – North America north of Mexico*. Houghton Mifflin Company, Boston.
- PLATANIA, S.P. 1990. The ichthyofauna of the Rio Grande drainage, Texas and Mexico, from Boquillas to San Ygnacio. U.S. Fish and Wildlife Service, Region 2, Final Report.
- PLATANIA, S.P., AND C.S. ALTENBACH. 1998. Reproductive strategies and egg types of seven Rio Grande basin cyprinids. *Copeia* 1998:559–569.
- SCHMIDT, J.C., B.L. EVERITT, AND G. A. RICHARD. 2003. Hydrology and geomorphology of the Rio Grande and implications for river rehabilitation. In: G.P. Garrett and N.L. Allan, editors. *Aquatic Fauna of the Northern Chihuahuan Desert*. Museum of Texas Tech University, Special Publications 46:25–45.
- SUBLETTE, J.E., M.D. HATCH, AND M. SUBLETTE. 1990. *The Fishes of New Mexico*. University New Mexico Press, Albuquerque, New Mexico.
- TEXAS NATURAL RESOURCE CONSERVATION COMMISSION. 1994a. Binational study regarding the presence of toxic substances in the Rio Grande/Rio Bravo and its tributaries along the boundary portion between the United States and Mexico: Texas Natural Resource Conservation Commission.

TEXAS NATURAL RESOURCE CONSERVATION COMMISSION. 1994*b*. The State of Texas water quality inventory. *Texas Natural Resource Conservation Commission* 3:709.

TEXAS NATURAL RESOURCE CONSERVATION COMMISSION. 1994*c*. Regional assessment of water quality in the Rio Grande Basin: Texas Natural Resource Conservation Commission.

TEXAS NATURAL RESOURCE CONSERVATION COMMISSION. 1995. Texas surface water quality standards: Texas Administrative Code, Title 30, Chapter 307.2-307.10, June 23, 1995.

TEXAS WATER COMMISSION. 1992*a*. The State of Texas water quality inventory: Texas Water Commission, LP 92-16.

TEXAS WATER COMMISSION. 1992*b*. Regional assessment of water quality in the Rio Grande basin: Texas Water Commission, GP 92-02.

U. S. FISH AND WILDLIFE SERVICE. 1999. Rio Grande silvery minnow recovery plan. Albuquerque, New Mexico.