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Diet and Reproduction of the Gray Redhorse (*Moxostoma congestum*) in a Texas Hill Country Stream and Reservoir

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ABSTRACT

Reproduction and diet of gray redhorse (*Moxostoma congestum*) were examined in a Texas Hill Country stream and a central Texas reservoir from September 2004 through August 2005. Temporal patterns in gonadosomatic index and oocyte diameter relative frequency indicated that *M. congestum* spawns over two distinct periods during spring and likely spawns multiple clutches in each period. *Moxostoma congestum* is an opportunistic benthic invertivore, with mollusks being the predominant food item in summer and aquatic insects the primary food item in other seasons. Additionally, diets differed between stream and reservoir habitats and among seasons. Though habitat degradation is of concern for *M. congestum*, our data suggest that it has persisted in habitats disturbed by low-head dam and mainstem reservoir construction due in part to its opportunistic feeding strategy that allows it to adapt to lentic systems.

INTRODUCTION

Moxostoma congestum is part of the autochthonous element of the ichthyofauna of the western Gulf Slope from the Brazos River to the Nueces River (Conner and Suttkus 1986). Additionally, its natural range extends into the Rio Grande drainage of Texas, New Mexico, and eastern Mexico (Jenkins 1980). Although *M. congestum* is listed as stable by Warren et al. (2000), Williams et al. (1989) listed it as a species of special concern due to habitat degradation. Streams within the distribution of *M. congestum* face several threats (Bowles and Arsuffi 1993) including large reservoirs and small water impoundments. Despite over 6,000 dams in Texas (Shuman 1995), *M. congestum* has persisted in many of these impounded systems.

Moxostoma congestum typically is found in upland and lowland rivers and streams (Conner and Suttkus 1986) and is often associated with deep, low current velocity, low turbidity habitats (Rose and Echelle 1981, Cantu and Winemiller 1997). The description of diet by Cowley and Sublette (1987) is consistent with the diet predicted by Eastman (1977) for most *Moxostoma* species based on pharyngeal teeth type, consisting of primarily benthic insects and thin shelled mollusks. However, the diet description of Cowley and Sublette (1987) is based on five individuals ranging from 100 to 250 mm and might not reflect adult diets or seasonal changes in diet. Reproductive behavior of *M. congestum* was described by Martin (1986) as occurring in March and April with spawning occurring over a two-day period and was similar to that of *M. lachneri* (Burr 1979). Although spawning was observed over a two-day period, Martin's (1986) period of observation did not preclude spawning events earlier or later in the year. Additionally, information on spawning preparedness and minimum size at first reproduction is lacking.

The purpose of our study was to provide information on diet and reproduction of *M. congestum* in a central Texas stream and in a mainstem reservoir. Specific objectives were to describe overall food habits as well as seasonal and habitat associated differences in diet and to describe trends in gonadosomatic index (GSI) and oocyte maturation. Additionally, comparisons of diet among stream and mainstem impoundment populations were made as *M. congestum* has persisted in several impounded systems.

METHODS AND MATERIALS

The Blanco River drains an area of 1,067 km^2 in the counties of Kendall, Comal, Blanco, and Hays in Texas, before its confluence with the San Marcos River. It is generally a shallow to moderate depth wadeable stream with substrate dominated by bedrock and gravel. Several low-head dams have been constructed on the Blanco River from the headwaters to its confluence with the San Marcos River. Canyon Lake (Comal County, Texas) is a 3,331 ha reservoir on the Guadalupe River with a mean depth of 13 m and a maximum depth of 48 m.

Fish were collected monthly from September 2004 through August 2005 from the pool of a low-head dam on the Blanco River near the town of Blanco and from Canyon Lake. In the Blanco River, individuals were collected with experimental gill nets. In Canyon Lake, individuals were collected by boat electrofishing. Because *M. congestum* is a large bodied fish with low relative abundance, 0.4% in the Blanco River (Bean et al., 2007), approximately three individuals per site were collected each month to avoid depletion of local populations. Each individual was measured for total length (TL) to the nearest millimeter and weighed to the nearest 25 g. All individuals were immediately killed by pithing. The gut tract and gonads were removed and preserved in a 10% formalin solution for diet and reproductive analysis.

In the laboratory, sex was determined by macroscopic examination of the gonads, and gonads were weighed to the nearest 0.01 g. A gonadosomatic index [GSI; (gonad weight/total weight)*100] was calculated for each individual. Mean GSI was calculated for males and females for each month. Diameters of 50 oocytes from each mature female were measured to the nearest 0.01 mm using a dissecting microscope equipped with a digital camera. Relative frequency histograms of oocyte diameter were constructed with 0.1 mm bins to determine spawning periodicity and frequency. A *t*-test was performed to test for differences in TL between males and females, and a chi-square test was performed to test for departure from a 1:1 sex ratio.

Gut contents, from the esophagus through the first loop of the gut, were identified to order, when possible, and weighed for each fish. Total weight of food type was used because several food types are not meaningfully countable (e.g., crushed mollusk shells). Unweighted means among fish for each food type category were calculated for each month. Bray-Curtis similarity indices were calculated for diets of each pairwise combination of individuals with diet data standardized as proportions of total weight of gut contents. Analysis of similarities (ANOSIM; Clarke and Green 1988, Clarke 1993) was used to test for differences in diet between the Blanco River and Canyon Lake and for seasonal effects.

RESULTS

Sixty *M. congestum* were collected for reproductive analysis. Fish were not collected in November 2004 due to flooding. Among individuals collected, six (204 to 337 mm TL) were immature, and their sex could not be determined by macroscopic gonadal examination. Mature females ($N = 34$) ranged from 260 to 497 mm TL. Mature males ($N = 20$) ranged from 285 to 468 mm TL. There was no difference in mean TL between males and females ($t_{0.05,52} = 1.91$, $P = 0.06$), and the sex ratio was not different from 1:1 ($\chi^2_{0.05,1} = 3.63$, $P = 0.06$).

Temporal patterns in GSI (Fig. 1) and oocyte diameter relative frequency (Fig. 2) indicated female gonadal quiescence from May to September. Recrudescence began in October with 100% of females possessing developing oocytes. Mean female GSI was greatest in February (12%) and diminished in March (5.4%) and April (1.9%) before quiescence. Additionally, mean male GSI ranged from 1% to 6% from December through April and was < 1% from May through October. Spent ovaries occurred in 75% of females in April, and 100% were spent in May. Mean GSI was < 1% from May to

September. Two size classes of oocytes were present from December to February, and one size class was present from March to April.

Sixty-two *M. congestum* were collected for diet analysis. Mean weight of food items in gut contents was 0.31 g. Food items consisted of aquatic insects (47%, unweighted mean across months), mollusks (42%), amphipods (5%), ostracods (3%), fish (1%), Hydrachnida (< 0.1%), algae (< 0.1%), plant seeds (< 0.1%), and unidentifiable insect parts (2%). Mean frequency of occurrence of detritus by month was 91%, and mean occurrence of substrate was 27%. Mean weight of detritus in gut contents was 0.3 g and mean weight of substrate was 0.04 g. Mean percentage of empty stomachs was 6% across months (unweighted mean).

Across months, aquatic insects composed the majority of *M. congestum* diets from October to May ranging from 42% in January to 71% in February (Table 1). From June to September, diets were primarily comprised of mollusks ranging from 56% in August to 84% in June. Most common aquatic insects were Diptera and Ephemeroptera larvae followed by Trichoptera, Odonata, Coleoptera, and Megaloptera. The most common mollusk was *Corbicula fluminea*. Other mollusks, including gastropods and bivalves, were not identifiable below class because their shells were too finely crushed.

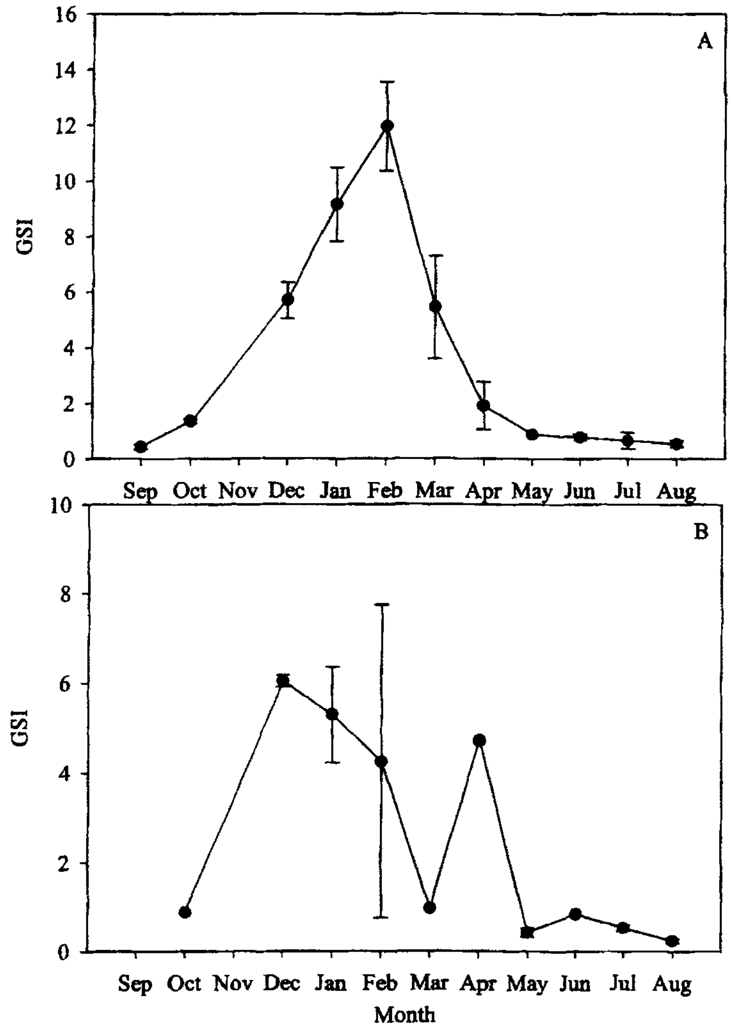

Figure 1. Monthly GSI ± SE of female (A) and male (B) *Moxostoma congestum* from the Blanco River and Canyon Lake, Texas, from September 2004 through August 2005.

Amphipods were relatively abundant in *M. congestum* stomachs in October (17%) and December (28%), while ostracods were abundant in December (14%) and March (19%).

Diets were significantly different between the Blanco River and Canyon Lake (Global R = 0.103, $P < 0.01$; Table 2) and between seasons (Global R = 0.067, $P = 0.04$). Mollusks were more abundant in fish from Canyon Lake, whereas ephemeropterans were more abundant in fish from the Blanco River. Summer *M. congestum* diets differed significantly from both winter (R = 0.183, $P < 0.01$) and spring (R = 0.117, $P = 0.03$) diets. Corresponding to these differences, winter and spring diets had greater proportions of aquatic insects, whereas summer diets had greater proportions of mollusks. No other pairwise comparisons among seasons demonstrated significant differences in diet.

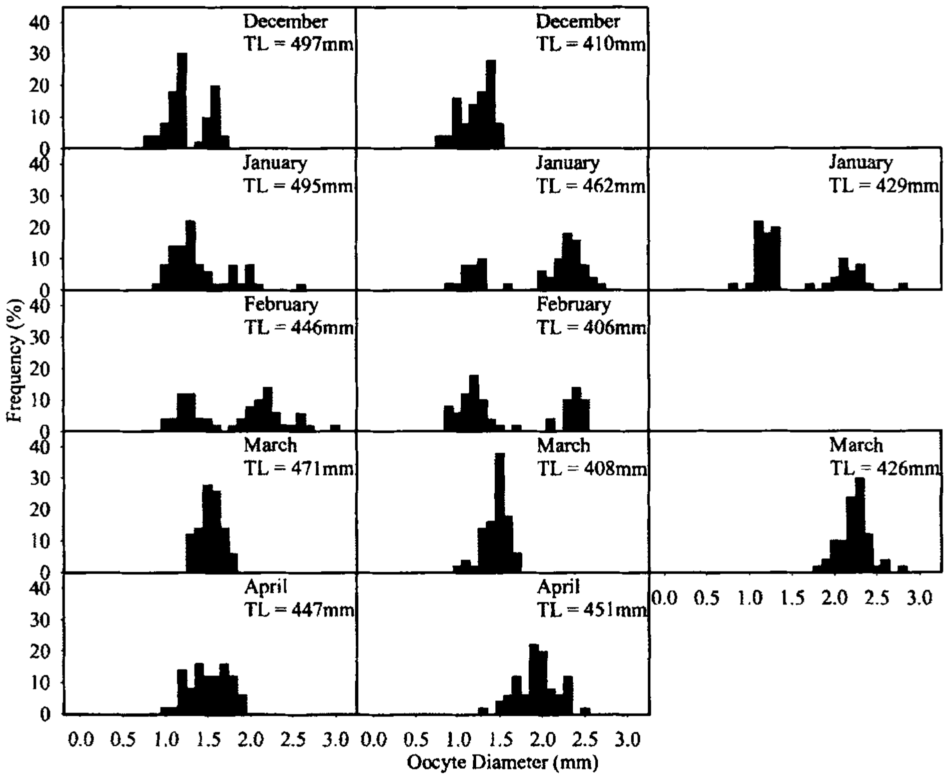

Figure 2. Oocyte diameter relative frequencies from *Moxostoma congestum* collected from the Blanco River and Canyon Lake, Texas, from December 2004 through April 2005.

DISCUSSION

Temporal patterns in GSI and oocyte diameter relative frequency suggested that *M. congestum* spawns over two distinct periods first in late February or early March and again in late April or early May. Resolution of data at the monthly level did not allow distinction between a single clutch or multiple clutches within each spawning period. However, Martin (1986) reported spawning in Walnut Creek, Texas, to occur within a two-day period with repeated spawning events within schools, lending support to the pattern of multiple clutches spawned over a short time in each period. Several species of *Moxostoma* spawn over a short one- to three-day period (Burr 1979, Jenkins and Jenkins 1980, and Kwak and Skelly 1992) whereas *M. valenciennesi* spawns over a period extending up to eight days (Cooke and Bunt 1999). Although sex could be identified in individuals as small as 260 mm TL, developing oocytes were not found in individuals

Table 1. Frequency of occurrence of empty stomachs and of detritus and substrate in stomachs, and relative abundance of food items in the gut contents of *Moxostoma congestum* collected from the Balnco River and Canyon Lake, Texas, from September 2004 through August 2005.

		Occurrence (%)			Relative abundance (%)								
Month	N	Empty stomachs	Detritus	Substrate	Aquatic insects	Mollusks	Amphipods	Ostracods	Hydrachnids	Fish	Algae	Plant seeds	Unidentifiable insects
Sep.	6	16.7	80.0	-	33.6	65.2	-	-	-	-	0.2	-	1.0
Oct.	5	-	100.0	60.0	53.9	19.6	16.5	-	-	-	-	-	10.0
Dec.	5	-	80.0	20.0	52.4	-	27.7	13.6	-	-	-	0.4	5.9
Jan.	7	-	100.0	14.3	41.9	41.3	3.8	-	<0.1	11.0	<0.1	-	2.0
Feb.	4	-	100.0	50.0	71.2	28.6	0.1	-	-	-	<0.1	-	-
Mar.	5	-	80.0	20.0	45.7	35.2	-	19.2	-	-	-	-	-
Apr.	8	-	100.0	37.5	64.6	32.4	0.9	2.1	<0.1	-	-	-	-
May	5	-	80.0	40.0	68.9	27.7	2.7	-	<0.1	-	<0.1	-	0.6
Jun.	6	33.3	100.0	-	13.5	83.6	2.8	-	-	-	-	-	-
Jul.	5	-	100.0	40.0	30.7	67.1	-	-	-	-	0.3	-	1.9
Aug.	6	16.7	80.0	20.0	42.8	56.2	-	1.0	-	-	-	-	-

Table 2. Results of ANOSIM tests for differences in diet between the Blanco River and Canyon Lake, Texas, and global and pairwise tests between seasons.

	R	P		R	P
Season			Site		
Global test	0.067	0.04	Global test	0.103	<0.01
Pairwise tests					
Fall vs. Winter	0.023	0.32			
Fall vs. Spring	0.034	0.27			
Fall vs. Summer	0.062	0.14			
Winter vs. Spring	-0.012	0.55			
Winter vs. Summer	0.183	<0.01			
Spring vs. Summer	0.117	0.03			

<392 mm. This suggested *M. congestum* is a late maturing species. Minimum age of mature *M. valenciennesi* (Cooke and Bunt 1999) and *M. erythrurum* (Kwak and Skelly 1992) of similar length is estimated at five to six years.

Analysis of diet indicated that *M. congestum* is a benthic invertivore and confirms the prediction of Eastman (1977) of a diet consisting primarily of benthic insects and thin shelled mollusks. The presence of algae, plant seeds, and fish in gut contents also suggested that *M. congestum* is somewhat opportunistic. Among aquatic insects, dipterans, particularly Chironomidae, were the most common food item suggesting that feeding takes place in calm waters of pools or stream edges (Timmons and Ramsey 1983). Ephemeropterans also comprised a large portion of the aquatic insects consumed by fish in this study. However, Cowley and Sublette (1987) did not report Ephemeroptera in *M. congestum* diets. Differences in diet between *M. congestum* from the Blanco River and Canyon Lake likely reflected differences in available foods and subsequent diet shifts in a novel environment (Loureiro-Crippa and Hahn 2006). Across seasons, significant differences in diet only occurred between winter and summer and between spring and summer. However, whether these seasonal differences in diet reflect differences in availability or consumption is not evident.

Despite being listed as a species of special concern by Williams et al. (1989) due to habitat degradation, *M. congestum* has persisted in systems disturbed by low-head and mainstem dams. For example, *M. congestum* has persisted in the Blanco River and was most abundant in deep pools of tributaries and in the impoundment above a low-head dam (Bean et al. 2007). These low-head dams likely create habitats similar to the pools and runs used by *M. congestum* in unimpounded stream reaches (Rose and Echelle 1981, Cantu and Winemiller 1997). The opportunistic-invertivorous feeding strategy of *M. congestum* has been associated with adaptability to reservoir habitats (Loureiro-Crippa and Hahn 2006). Although *M. congestum* has persisted in impounded streams, it has declined in areas where reduced discharge has diminished water quality (Hoagstrom 2001). Additionally, groundwater pumping is among the greatest threats to the ichthyofauna of Texas Hill Country streams (Bowles and Arsuffi 1993). If excessive groundwater pumping and drought lead to local extirpations of *M. congestum* due to reduced discharge or reduced water quality, the presence of low-head dams may inhibit recolonization.

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LITERATURE CITED

Bean, P. T., T. H. Bonner, and B. M. Littrell. 2007. Spatial and temporal patterns in the fish assemblage of the Blanco River, Texas. Texas Journal of Science 59:179-200.

Bowles, D. E. and T. L. Arsuffi. 1993. Karst aquatic ecosystems of the Edwards Plateau region of central Texas, USA: a consideration of their importance, threats to their existence, and efforts for their conservation. Aquatic Conservation: Marine and Freshwater Ecosystems 3:317-329.

Burr, B. M. 1979. Observations on spawning and breeding coloration of *Moxostoma lachneri* in Chattahoochee River, Georgia. Georgia Journal of Science 37:205-207.

Cantu, N. E. V. and K. O. Winemiller. 1997. Structure and habitat associations of Devils River fish assemblages. Southwestern Naturalist 42:265-278.

Clarke, K. R. and R. H. Green. 1988. Statistical design and analysis for a 'biological effects' study. Marine Ecology Progress Series 46:213-226.

Clarke, K. R. 1993. Non-parametric multivariate analyses of changes in community structure. Australian Journal of Ecology 18:117-143.

Cooke, S. J. and C. M. Bunt. 1999. Spawning and reproductive behavior of the greater redhorse, *Moxostoma valenciennesi*, in the Grand River, Ontario. The Canadian Field-Naturalist 113:497-502.

Conner, J. V. and R. D. Suttkus. 1986. Zoogeography of freshwater fishes of the western gulf slope of North America. Pages 413-456 *In:* Hocutt, C. H. and E. O. Wiley (eds.), The zoogeography of North American freshwater fishes. John Wiley & Sons, Inc., New York, 880 pp.

Cowley, D. E. and J. E. Sublette. 1987. Food habits of *Moxostoma congestum* and *Cycleptus elongatus* (Catostomidae: Cypriniformes) in Black River, Eddy County, New Mexico. Southwestern Naturalist 32:411-413.

Eastman, J. T. 1977. The pharyngeal bones and teeth of catostomid fishes. American Midland Naturalist 97:68-97.

Hoagstrom, C. W. 2001. Historical and recent fish fauna of the lower Pecos River. *In:* Garrett, G. P. and N. L. Allan (eds.), Aquatic fauna of the northern Chihuahua Desert. Museum of Texas Tech University, Special Publications 46:91-109.

Jenkins, R. E. 1980. *Moxostoma congestum* (Baird and Girard), Gray Redhorse. Page 418 *In:* Lee, D. S., C. R. Gilbert, C. H. Hocutt, R. E. Jenkins, D. E. McAllister, and J. R. Stauffer, Jr. (eds.), Atlas of North American freshwater fishes. North Carolina State Museum of Natural History, Raleigh.

Jenkins, R. E. and D. J. Jenkins. 1980. Reproductive behavior of the greater redhorse, *Moxostoma valenciennesi*, in the Thousand Islands region. The Canadian Field-Naturalist 94:426-430.

Kwak, T. J. and T. M. Skelly. 1992. Spawning habitat, behavior, and morphology as isolating mechanisms of the golden redhorse, *Moxostoma erythrurum*, and the black redhorse, *M. duquesnei*, two syntopic fishes. Environmental Biology of Fishes 34:127-137.

Loureiro-Crippa, V. E. and N. S. Hahn. 2006. Use of food resources by the fish fauna of a small reservoir (rio Jordão, Brazil) before and shortly after its filling. Neotropical Ichthyology 4:357-362.

Martin, R. F. 1986. Spawning behavior of the gray redhorse, *Moxostoma congestum* (Pisces: Catostomidae) in central Texas. Southwestern Naturalist 31:399-401.

Rose, D. R. and A. A. Echelle. 1981. Factor analysis of associations of fishes in Little River, central Texas, with an interdrainage comparison. American Midland Naturalist 106:379-391.
Shuman, J. R. 1995. Environmental considerations for assessing dam removal alternatives for river restoration. Regulated Rivers: Research & Management 11:249-261.
Timmons, T. J. and J. S. Ramsey. 1983. Life history and habitat of the blackfin sucker, *Moxostoma atripinne* (Osteichthyes: Catostomidae). Copeia 1983:538-541.
Warren, M. L., Jr., B. M. Burr, S. J. Walsh, H. L. Bart, Jr., R. C. Cashner, D. A. Etnier, B. J. Freeman, B. R. Kuhajda, R. L. Mayden, H. W. Robison, S. T. Ross, and W. C. Starnes. 2000. Diversity, distribution, and conservation status of the native freshwater fishes of the southern United States. Fisheries 25:7-31.
Williams, J. E., J. E. Johnson, D. A. Hendrickson, S. Contreras-Balderas, J. D. Williams, M. Navarro-Mendoza, D. E. McAllister, and J. E. Deacon. 1989. Fishes of North America endangered, threatened, or of special concern: 1989. Fisheries 14:2-20.

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