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Hyperkyphosis in longnose gar (*Lepisosteus osseus*) of north central Texas

Samuel W. Kelley
U.S. Geological Survey, Wichita Falls, Texas, skelley@usgs.gov

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HYPERKYPHOSIS IN LONGNOSE GAR (*LEPISOSTEUS OSSEUS*) OF NORTH CENTRAL TEXAS

Samuel W. Kelley[1]

ABSTRACT.—Two mature female longnose gar (*Lepisosteus osseus*) exhibiting severe hyperkyphotic spinal deformities were captured during the 2010 spring spawn at Lake Arrowhead, Clay County, Texas. Yet, despite their deformities and impaired motility, both longnose gar were in overall good condition. Hyperkyphosis in both longnose gar resulted from fused trunk vertebrae in the affected areas. Results of morphological examinations and computerized tomography (CT) scans showed no evidence of injury-induced responses and suggested a congenital or possibly environmentally induced aetiology for disruption of the normal vertebral segmentation process.

RESUMEN.—Dos hembras adultas del pejelagarto narigudo (*Lepisosteus osseus*) con severas deformidades espinales hipercifóticas fueron capturadas durante la desovación primaveral del 2010 en Lake Arrowhead, condado de Clay, Texas. No obstante, a pesar de sus deformidades y limitada motilidad, ambos pejelagartos estaban en buenas condiciones generales. La hipercifosis en ambos pejelagartos narigudos resultó de la fusión de vértebras del tronco en las áreas afectadas. Las evaluaciones morfológicas y de tomografía computarizada (TC) no mostraron evidencia de respuestas inducidas por lesiones, y sugirieron una etiología congénita o posiblemente inducida por el ambiente para la interferencia del proceso normal de segmentación vertebral.

Two female longnose gar (*Lepisosteus osseus*, hereafter gar) exhibiting a hyperkyphotic (humpbacked) condition (Fig. 1) were captured using archery (bowfishing) equipment on 25 April 2010 at Lake Arrowhead, Clay County, Texas. Lake Arrowhead was impounded in 1966 by the damming of Little Wichita River. The lake has a surface area of approximately 6036 ha, a maximum depth of about 14 m near the dam, high turbidity, and high pool-elevation fluctuation (1.2–1.8 m) due to extensive municipal water use by the city of Wichita Falls (approximately 24 km to the northwest) and neighboring communities. The 2 fish were captured amongst other actively spawning gar near the East Little Post Oak Creek Bridge (33.656347°N, 98.411583°W) in the lower portion of the reservoir.

Total length (TL, mm) and mass (nearest 5 g) of the 2 specimens were measured, and observations of stomach contents and age were made. Gravimetric estimations of total egg counts were made from total ovary masses and subset egg counts (Johnson and Noltie 1997). Age was determined by counting annuli on the largest branchiostegal rays from each fish (Netsch and Witt 1962). The largest left-side branchiostegal rays were removed from each gar, boiled in water for approximately 10 minutes, and stripped of all soft tissue. The branchiostegal rays were then briefly soaked in a diluted Clorox® solution (Klaassen and Morgan 1974) and cleared in mineral oil; annuli bands that extended completely across the ray were counted using a dissecting microscope (Johnson and Noltie 1997, Love 2004). The gar were eviscerated, and the ganoid scales were carefully removed using metal snips so the underlying musculature could be examined and to facilitate efficacious computerized tomography (CT) scans of the abnormal areas. CT scans of the vertebral columns of both anomalous gar were compared to those of a normal female gar of comparable size captured the same day. Scans were conducted at Wilbarger General Hospital, Vernon, Texas, using a 64-channel multidetector CT scanner (Brilliance CT 64-channel scanner, Philips Medical Systems, Cleveland, OH).

The larger of the 2 deformed gar had a TL of 1251 mm and a mass of 7455 g; the estimated egg count was 47,360, and age was 19 years. The smaller malformed gar had a TL of 1126 mm and a mass of 4705 g; the estimated egg count was 39,444, and age was 9 years. Neither of the 2 deformed gar had spawned, evidenced by ovaries that were filled completely with eggs. The normal female gar had a TL of 1143 mm, a mass of

[1]U.S. Geological Survey, 3010 Buchanan St., Wichita Falls, TX 76308. E-mail: skelley@usgs.gov

Fig. 1. A and B, two hyperkyphotic female gar (A, 19 years old; B, 9 years old) in spawning condition captured 25 April 2010 from Lake Arrowhead, Clay County, Texas; arrows indicate deformed regions; C, a comparable normal female gar (15 years old) in spawning condition captured on the same day at the same location.

4790 g, and an age of 15 years; comparative total estimated egg counts were not made due to substantial egg releases already incurred by spawning activity.

The larger deformed gar had 4 partially digested gizzard shad (*Dorosoma cepadianum*) in its stomach, and the smaller gar had one unidentifiable digested baitfish (probably *Dorosoma* sp.) in its stomach; the normal female's stomach was empty. Prior to capture, both kyphotic gar were briefly observed exhibiting abnormal swimming behavior with constricted, stiff, and awkward movements; however, both appeared to be in good overall condition, evidenced by significant quantities of visceral fat. Moreover, both the 19-year-old and 9-year-old kyphotic longnose gar exceeded both the weighted mean calculated length of equal-age longnose gar ($\bar{x}_{19}$ = 1194 mm, $\bar{x}_9$ = 958 mm) and the fecundity estimates (mean egg count = 30,000+) of the top 50% of captured female longnose gar from streams in Missouri (Netsch and Witt 1962). Likewise, the smaller kyphotic gar exceeded the mean total length for 9-year-old female longnose gar from a Kansas reservoir ($\bar{x}$ = 1013 mm; Klaassen and Morgan 1974), while both kyphotic longnose gar fell well within the range of 88% of lengths (900–1400 mm) and 85% of weights (3–10 kg) of female longnose gar from 2 large streams in southwestern Oklahoma (Tyler et al. 1994). Despite their deformities, both females were actively participating in prespawning activities, including being corralled by multiple smaller males on the water's surface near rocky spawning grounds, continuous audible gulping (despite normal dissolved oxygen levels), and breaching/popping of the rostrum against the water surface.

No evidence of scarring on the external or internal sides of the scale armor near the deformed trunk regions was observed in either gar, though slight scarring was occasionally evident in other nonaffected areas. However, the larger gar had a small area of increased spacing among interlocking scales directly superior to the kyphotic region. This increased spacing was likely due to years of excessive angular stress placed on those scales and subsequent interstitial deposition of ganoine. Scar tissue or other evidence of mechanical damage to the epaxial musculature was not apparent in the deformed areas of either specimen after the scale armor was removed.

CT scans of the axial skeletons revealed anteroposterior compression, as well as abnormal fusion and articulation of 3 trunk vertebrae (numbers 26–28) in the larger specimen and 4 trunk vertebrae (numbers 22–25) in the smaller specimen.

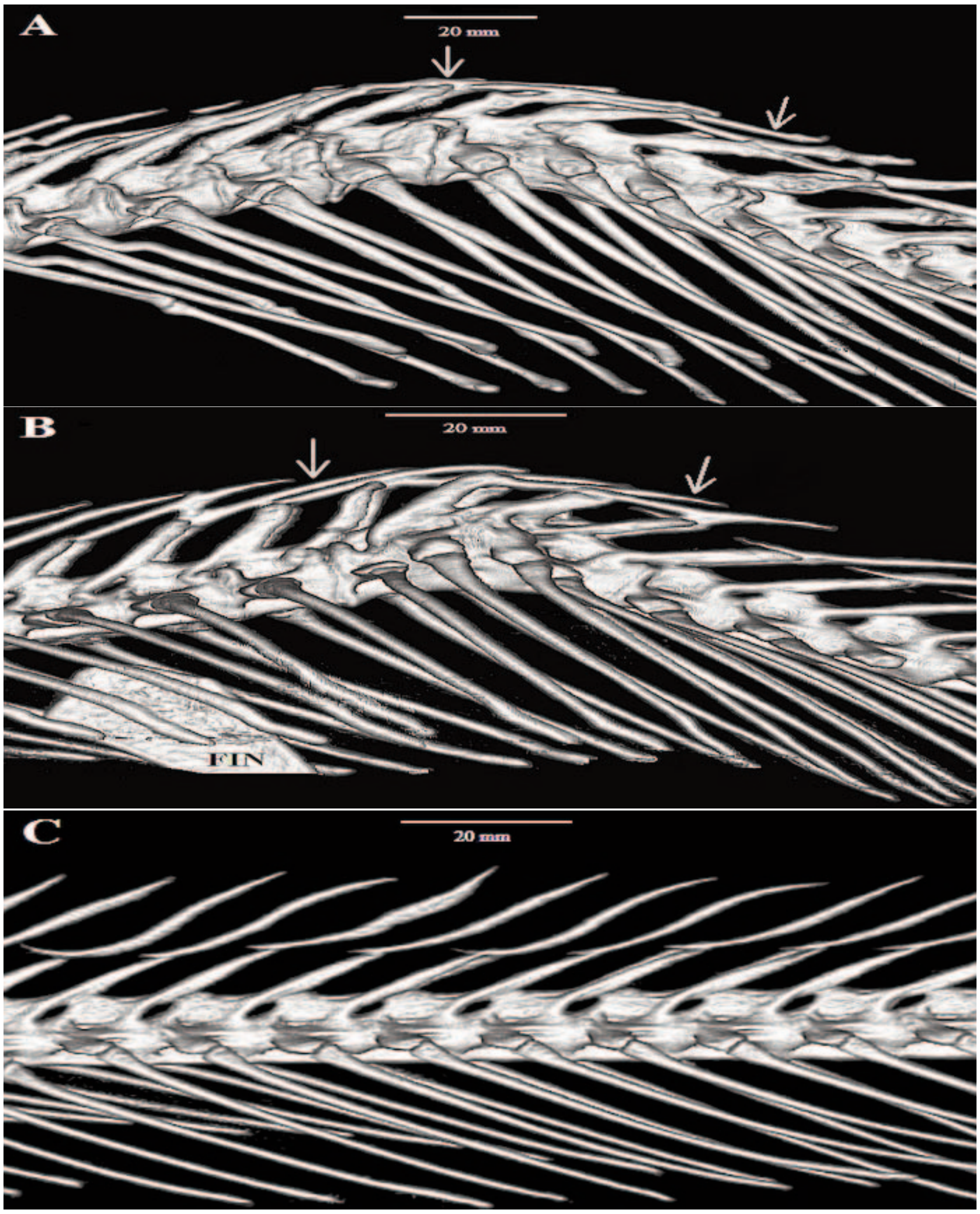

Fig. 2. A and B, lateral CT scans of 2 hyperkyphotic female gar (A, 19 years old; B, 9 years old) in spawning condition captured 25 April 2010 from Lake Arrowhead, Clay County, Texas; C, a comparable normal female gar (15 years old) in spawning condition captured the on the same day at the same location. Anterior is oriented to the left, and fused vertebrae lie between the arrows.

CT scans also revealed distorted centra and hyperdorsal displacement of basapophyses and adjoining ventral ribs (Figs. 2, 3), particularly in the smaller gar. The obtusely angled apex (approximately 136 for the larger gar and approximately 138 for the smaller gar) and fusion of both vertebral columns resulted in hyperkyphosis in both specimens. Neural spines in the kyphotic regions of both gar were markedly flattened against the spinal column in comparison to a normal gar, probably as a result of compression against the rigid dorsal-scale armor (Fig. 2). Although neural spines and neural zygopophses in the abnormal gar were oriented in atypical

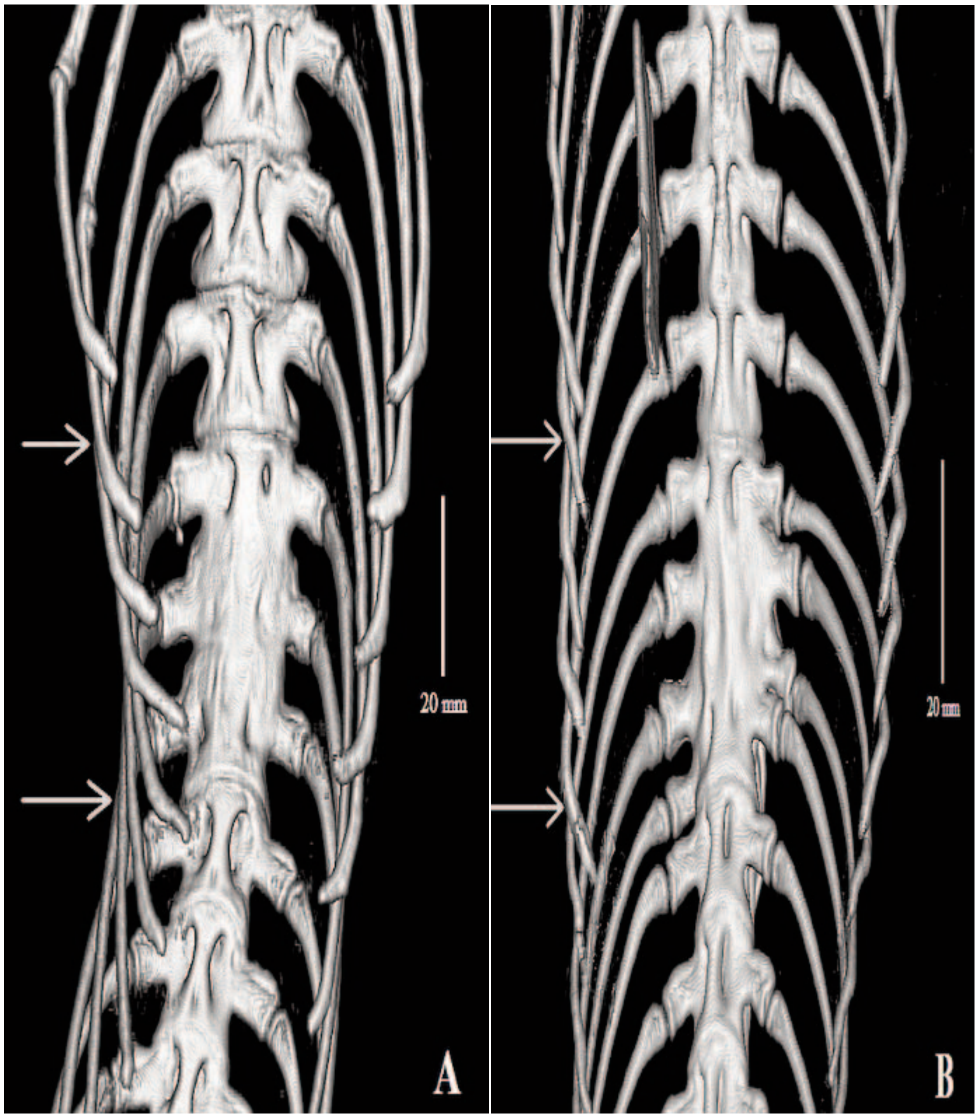

Fig. 3. A and B, vertical CT scans displaying the fused vertebrae of 2 hyperkyphotic female gar (A, 19 years old; B, 9 years old) in spawning condition captured 25 April 2010 from Lake Arrowhead, Clay County, Texas. Anterior is oriented to the top; view is ventral; and fused vertebrae lie between the arrows.

positions, they did not appear to be physically damaged, nor were there any visible indicators of previous injuries (e.g., healed fracture lines). Additionally, the kyphotic spinal regions of both gar did not show evidence of dystrophic calcification or metaplastic replacement by fibrocartilaginous elements around the fused vertebrae, as might be expected in response to severe injury.

Previous reports of skeletal anomalies in the longnose gar (Kroger and Guthrie 1973) and the spotted gar (*L. oculatus;* Tyler 1987) exist, but this is the first reported case of kyphosis in either species. Although vertebral fusion is known to occur among mammalian vertebrates in response to injury, fusion requires a type-III injury, in which the opposing endplates of juxtaposed centra and the intervertebral disc are both substantially injured (Korres et al. 2000). Whether piscine vertebrae respond in a predictable, similar fashion is unknown; however, previous research has demonstrated some cases of almost total regeneration of severed spinal columns in goldfish (Bignami et al. 1974). In addition, some evidence exists regarding vertebral fusion in fish as a result of trauma from electric shock (Dalbey and McMahon 1996). However, Roach (1992), who studied electrofishing-induced injuries to the morphologically similar northern pike (*Esox lucius*), indicated that very few pike (5%–12%) incurred significant fractured or separated vertebral columns from electrofishing activities, and all pike with such injuries also suffered from severe internal hemorrhaging, though 92% of shocked pike survived. Moreover, though electrofishing activities by the Texas Parks and Wildlife Department (TPWD) have been conducted on a regular basis in Lake Arrowhead since 1988, very few gar seem to be impacted by this activity (M. Howell, TPWD fisheries biologist, personal communication); however, such observations may be skewed by the fact that electrically stunned gar often sink rapidly to the bottom, rather than float up to the water's surface (Burr 1931).

Skeletal deformities in fish and other vertebrates have been attributed to several possible causes such as response to injury or electric shock (e.g., electrofishing), genetic factors, unfavorable developmental conditions, or metal pollutants, among others (Sloof 1982). Lepisosteids have been recognized as important environmental indicator and biomarker species (Hartley et al. 1996, Huang et al. 1997, Huggett et al. 2001, Burger et al. 2004) because of their resilience, predatory habits, and high potential for biomagnification of environmental toxins. Notorious bioaccumulating pollutants include mercury (Valentine 1975), selenium (Lemly 1993), cadmium (Eaton 1974), lead (Holcombe et al. 1976), zinc (Bengtsson 1974), and arsenic (Willhite 1981), several of which are released by coal-fired power plants in fly ash (often used in road construction) or vented as airborne emission by-products. These contaminants may be carried by prevailing winds or runoff, dispersing far from their point of origin and into area surface waters.

No chemical testing of the anomalous gar tissues was performed due to limited funding and the high cost of such tests which may exceed $2000 per sample (K. Wiles, Texas Department of State Health Services, personal communication). However, a recent analysis of lake sediment, lake water, and tributary water from Lake Arrowhead by Wilson et al. (2008) revealed sediment sample concentrations exceeding the respective threshold-effect concentration (Ingersoll et al. 2001) for arsenic, chromium, copper, lead, and nickel, but below the probable-effect concentrations; no testing for mercury compounds was attempted.

Determining aetiology in these 2 cases, whether via deleterious/polluted environmental conditions, injury, or congenital mutations, remains difficult. If bioaccumulating pollutants caused these deformities, other fish species in the lake should, on occasion, exhibit similar conditions; however, no known records of skeletal deformities from abundant neighboring game fish (e.g., white crappie, white bass, blue catfish) or rough fish (e.g., spotted gar, shortnose gar, drum, smallmouth buffalo, bigmouth buffalo, common carp) exist from Lake Arrowhead, though such cases may go unreported. Additionally, evidence from the CT scans coupled with the known developmental processes of lepisosteid vertebrae provides helpful insights. No evidence of previous segmentation, metaplasia, or osteogenic healing was visible in the fused vertebrae of either hyperkyphotic gar (Figs. 2, 3). If hyperkyphosis in these gar resulted from injury, then evidence of such injuries should manifest in those vertebrae; however, injuries incurred at very early (i.e., larval) life stages may not be readily apparent. Lepisosteid vertebrae are also unique in that they are opisthocoelous—the only such vertebrae known among extant fish. Furthermore, unlike the advanced teleosts, the completely ossified centra in *Lepisosteus* form by endochondral replacement of perichordal mesenchyme, and segmentation of those centra occurs only after the formation of the opisthocoelous joint (Laerm 1982). Thus, the complete absence of segmentation in these fused gar vertebrae, and the lack of evidence for either an injury or pollutant-related cause, suggests a congenital aetiology for disruption of the normal ontogeny in these fused opisthocoelous joints.

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LITERATURE CITED

BENGTSSON, B.E. 1974. Vertebral damage to minnows, *Phoxinus phoxinus*, exposed to zinc. Oikos 25:134–139.

BIGNAMI, A., L. FORNO, AND D. DAHL. 1974. The neuroglial response to injury following spinal cord transection in the goldfish. Experimental Neurology 44:60–70.

BURGER, J., E.F. ORLANDO, M. GOCHFELD, G.A. BINCZIK, AND L.J. GUILLETTE, JR. 2004. Metal levels in tissues of Florida gar (*Lepisosteus platyrhincus*) from Lake Okeechobee. Environmental Monitoring and Assessment 90:187–201.

BURR, J.G. 1931. Electricity as a means of garfish and carp control. Transactions of the American Fisheries Society 61:174–182.

DALBEY, S.R., AND T.E. MCMAHON. 1996. Effect of electrofishing pulse shape and electrofishing-induced spinal injury on long-term growth and survival of wild rainbow trout. North American Journal of Fisheries Management 16:560–569.

EATON, J.G. 1974. Chronic cadmium toxicity to the bluegill (*Lepomis macrochirus* Rafinesque). Transactions of the American Fisheries Society 103:729–735.

HARTLEY, W.R., A. THIYAGARAJAH, AND A.M. TREINIES. 1996. Liver lesions in the gar fish (*Lepisosteidae*) as biomarkers of exposure. Marine Environmental Research 42:217–221.

HOLCOMBE, G.W., D.A. BENOIT, E.N. LEONARD, AND J.M. MCKIM. 1976. Long-term effects of lead exposure on three generations of brook trout (*Salvelinus fontinalis*). Journal of the Fisheries Research Board of Canada 33:1731–1741.

HUANG, T.L., P.O. OBIH, R. JAISWAL, W.R. HARTLEY, AND A. THIYAGARAJAH. 1997. Evaluation of liver and brain esterases in the spotted gar fish (*Lepisosteus oculatus*) as biomarkers of effect in the lower Mississippi River basin. Bulletin of Environmental Contamination and Toxicology 58:688–695.

HUGGETT, D.B., J.A. STEEVENS, J.C. ALLGOOD, C.B. LUTKEN, C.A. GRACE, AND W.H. BENSON. 2001. Mercury in sediment and fish from North Mississippi Lakes. Chemosphere 42:923–929.

INGERSOLL, C.G., D.D. MACDONALD, N. WANG, J.L. CRANE, L.J. FIELD, P.S. HAVERLAND, N.E. KEMBLE, R.A. LINDSKOOG, C. SEVERN, AND D.E. SMORONG. 2001. Predictions of sediment toxicity using consensus-based freshwater sediment quality guidelines. Archives of Environmental Contamination and Toxicology 41:8–21.

JOHNSON, B.L., AND D.B. NOLTIE. 1997. Demography, growth, and reproductive allocation in stream spawning gar. Transactions of the American Fisheries Society 126:438–466.

KLAASSEN, H.E., AND K.L. MORGAN. 1974. Age and growth of gar in Tuttle Creek Reservoir, Kansas. Transactions of the American Fisheries Society 103:402–405.

KORRES, D.S., G.C. BABIS, H. PARASKEVAKOU, S. KONSTANTINOS, J. TSAROUCHAS, AND V. LYKOMITROS. 2000. Spontaneous interbody fusion after controlled injuries to the spine: an experimental study in rabbits. Journal of Spinal Disorders and Techniques 13:31–35.

KROGER, R.L., AND J.F. GUTHRIE. 1973. Additional anomalous menhaden and other fishes. Chesapeake Science 14:112–116.

LAERM, J. 1982. The origin and homology of the neopterygian vertebral centrum. Journal of Paleontology 56: 191–202.

LEMLY, A.D. 1993. Teratogenic effects of selenium in natural populations of freshwater fish. Ecotoxicology and Environmental Safety 26:181–204.

LOVE, J.W. 2004. Age, growth, and reproduction of spotted gar (*Lepisosteus oculatus*), from the Lake Pontchartrain estuary, Louisiana. Southwestern Naturalist 49:18–23.

NETSCH, N.F., AND A. WITT JR. 1962. Contributions to the life history of the gar, (*Lepisosteus osseus*) in Missouri. Transactions of the American Fisheries Society 91: 251–262.

ROACH, S.M. 1992. Injury, survival, and growth of northern pike captured by electrofishing, Fishery Manuscript 92-3, Alaska Department of Fish and Game, Anchorage, AK.

SLOOF, W. 1982. Skeletal anomalies in fish from polluted surface waters. Aquatic Toxicology 2:157–173.

TYLER, J.D. 1987. Spotted gar with deformed mandible. Proceedings of the Oklahoma Academy of Science 67:81.

TYLER, J.D., J.R. WEBB, T.R. WRIGHT, J.D. HARGETT, K.J. MASK, AND D.R. SCHUKER. 1994. Food habits, sex ratios, and size of longnose gar in southwestern Oklahoma. Proceedings of the Oklahoma Academy of Science 74:41–42.

VALENTINE, D.W. 1975. Skeletal anomalies in marine teleosts. Pages 695–718 *in* W.E. Ribelin and G. Migaki, editors, The pathology of fishes. University of Wisconsin Press, Madison, WI.

WILLHITE, C.C. 1981. Arsenic-induced axial skeletal (dysgraphic) disorders. Experimental and Molecular Pathology 34:145–158.

WILSON, J.T., M. MUSGROVE, M.M. HAYNIE, AND P.C. VAN METRE. 2008. Physicochemical and analytical data for tributary water, lake water, and lake sediment, Lake Arrowhead, Clay and Archer counties, Texas, 2006. Data Series 334, U.S. Geological Survey, Reston, VA.

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