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DISTRIBUTION AND STATUS OF THE CHIHUAHUA CHUB (TELEOSTEI: CYPRINIDAE: *GILA NIGRESCENS*), WITH NOTES ON ITS ECOLOGY AND ASSOCIATED SPECIES

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ABSTRACT—Surveys in the historic range of the Chihuahua chub, *Gila nigrescens* (Girard) (Mimbres River in New Mexico, Guzmán and Laguna Bustillos basins in Chihuahua, México) during 1987–1991 documented current distribution and status, life history attributes and habitat, and factors contributing to the decline of the species. The Chihuahua chub has decreased dramatically in range and abundance during the past century, and is now comparatively common only in remote areas relatively free of habitat modification. Most populations consisted of individuals ≤100 mm standard length; males were smaller than females. Chihuahua chub were usually found in pools associated with tree root masses in permanently watered stream reaches. It was rare or absent where non-native fishes (particularly potential predators) were common. The high habitat specificity of the Chihuahua chub and widespread destruction of its habitat are likely the main reasons for the much reduced range and abundance of the species.

RESUMEN—Investigaciónes en el habitat histórico del charalito Chihuahuense, *Gila nigrescens* (Girard), (Río Mimbres, Nuevo México USA, y las cuencas de Guzmán y Laguna de Bustillos, Chihuahua México) durante 1987–1991 documentaron la distribución y estado actual, parámetros de vida histórica, habitat, y factores que contribuyen a la declinación del especie. El charalito Chihuahuense ha disminuido dramáticamente en distribución y abundancia durante el siglo pasado, y al presente es comparativamente común solamente en áreas relativamente libre de modificación del habitat. Las más de las poblaciones consiten de individuos de ≤100 mm de longitud estandar; machos fueron mas pequeños que hembras. Charalito Chihuahuense fue usualmente encontrado en charcos asociados con montónes de raicés de arboles en aguas de corriente permanente. Fue raro o ausente donde fueron comunes peces exóticos (particularmente predadores potenciales). El alto nivel de especificidad en cuanto a preferencia de habitat que requiere el charalito Chihuahuense y amplia destrucción de este tipo de habitat probablemente son las razónes principales por la gran desminución de distribución y abundancia del especie.

The Chihuahua chub, *Gila nigrescens* (Girard), is native to the Guzmán and Laguna Bustillos basins in Chihuahua, México and the Mimbres River in New Mexico (Smith and Miller, 1986). Published accounts of its distribution are sparse and little information is available on its life history or habitat associations. It was first collected in the Mimbres River in 1851 (Baird and Girard, 1854), but not again found there until 1975 (Sublette et al., 1990). In Chihuahua, it was first collected in the Casas Grandes drainage at Boca Grande, Río Janos (=San Pedro) in 1854 (Girard, 1856). Thereafter, the species was incidentally collected in other drainages of the Guzmán and Laguna Bustillos basins; records include those reported by Meek (1902, 1903) and Espinosa-Aguilar (1988) and additional records at Arizona State University Museum (ASU), United States National Museum (USNM), and University of Michigan Museum of Zoology (UMMZ). No systematic survey was made until Miller and Chernoff (1979) sampled sites of

known historic occurrence. Subsequent collections were reported by Espinosa-Aguilar (1988) or curated at ASU and UMMZ.

The taxonomic history of the Chihuahua chub is relatively complex (Miller and Chernoff, 1979). After Baird and Girard (1854) described the form in the Mimbres River as *Gila pulchella,* Girard (1856) described specimens from the Río Janos as *Tigoma nigrescens.* Although *pulchella* preceded *nigrescens,* it was a *nomen nudum* because Günther (1868) combined *Gila* with *Leuciscus,* thereby bringing *Gila pulchella* into secondary homonymy with *Leuciscus pulchella* (a synonym of the eastern fallfish, *Semotilus corporalis*). Further confusing the taxonomic status (and occurrence records) of Chihuahua chub was treatment of a Rio Grande form of chub as *Gila nigrescens* (e.g., Bailey et al., 1960, 1970). Miller (1961) and Miller and Hubbs (1962) clarified that issue by distinguishing *G. nigrescens* from the Rio Grande chub, *G. pandora. Gila nigrescens* is currently recognized as the valid name for the chub of the Mimbres River and Guzmán and Laguna Bustillos basins. However, Miller and Chernoff (1979) stated that the Laguna Bustillos form was distinguishable (at an undefined level) from the Guzmán form. Furthermore, R. R. Miller (pers. comm.) believed the Mimbres River was not consistently confluent with the Guzmán Basin during the Pleistocene, suggesting that the Mimbres and Guzmán forms may be separable.

Gila nigrescens is listed as endangered in the state of New Mexico (New Mexico Department of Game and Fish, 1976) and as a federally threatened species (United States Fish and Wildlife Service, 1983). Reasons for its reduced range and abundance in New Mexico include modification of habitat by agricultural and flood control practices, and establishment of non-native fish species (United States Fish and Wildlife Service, 1983). In Chihuahua, water quality degradation, surface water diversion, groundwater pumping, stream channelization, and introduction of non-native fishes have contributed to its decline (Miller and Chernoff, 1979).

Our purpose here is to document the current distribution and status of the Chihuahua chub throughout its range. In addition, we present information on its life history, habitat associations, and associated species.

METHODS—The Mimbres Drainage, except headwater reaches above the Cooney Place and McKnight Canyon (Fig. 1) where there are only non-native salmonids, was systematically sampled from 1987 through 1991. In Chihuahua, field work was accomplished in March 1990; there, we focused on areas where the probability of finding Chihuahua chub was good. Where access was particularly difficult, we bracketed reaches of perennial water to document extent of occurrence of Chihuahua chub and other fishes.

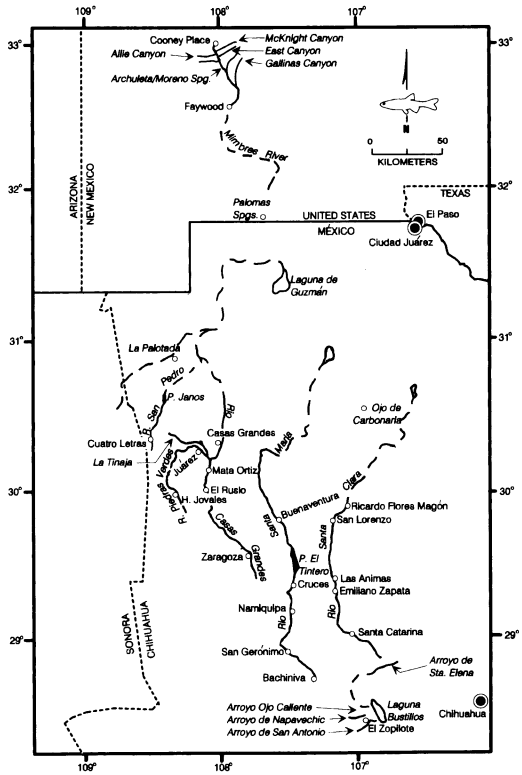

FIG. 1—Drainages of southwestern New Mexico, USA and northwestern Chihuahua, México.

We selected sample sites in Chihuahua based upon review of the limited literature, interviews with local residents, accessibility, and suggestions from ichthyologists familiar with the region. Many areas of limited or no previous sampling were inventoried, but some sites of historic occurrence were not sampled because they were permanently or seasonally dry, severely modified, or otherwise deemed unlikely to support Chihuahua chub.

Several springs near Columbus, New Mexico and Las Palomas, Chihuahua were not sampled. There were no literature or museum records suggesting that Chihuahua chub historically inhabited these springs (Palomas Springs); only beautiful shiner (*Cyprinella formosa*), fathead minnow (*Pimephales promelas*), and *Cyprinodon* sp. were known from them (W. L. Minckley, pers. comm.). Nor were the springs at Ojo de

Carbonaria in the Bolsón de los Muertos between the termini of the ríos Santa Maria and del Carmen sampled. Chernoff and Miller (1982) reported only bigmouth shiner (*Cyprinella bocagrande*), and Carbonaria pupfish (*Cyprinodon fontinalis*), isolated endemics, and non-native black bullhead (*Ameiurus melas*). Subsequently, Mayden and Hillis (1990) also found presumably non-native Río Grande cichlid (*Cichlosoma cyanoguttatum*).

Records of curated specimens were provided by the Academy of Natural Sciences, Philadelphia (ANSP), ASU, UMMZ, University of New Mexico Museum of Southwestern Biology (MSB), and USNM. These data plus those provided in published papers and theses were used to reconstruct the probable historical distribution of *G. nigrescens*.

Place names and geographic features in Chihuahua varied among available maps. We used 1:250,000 topographic maps published by Dirección General de Geografía as the authority. Where a particular physical feature or town received other names in the literature we parenthetically provide the equivalent. Place names in New Mexico follow 7.5′ and 15′ United States Geological Survey topographic maps. Smith and Miller (1986) was considered the authority on the historic ichthyofauna of the Laguna Bustillos and Guzmán basins. Koster (1957) and Smith and Miller (1986) were considered the authorities for the native fish fauna of the Mimbres River.

Most specimens were obtained with 12- or 24-volt, direct current, battery-powered, backpack electrofishers. One electrofishing pass was made in an upstream direction at each site, and stunned fish were captured with dipnets. Seines (4.6 by 1.8 m, 0.5 cm mesh) were used where habitat was debris-free isolated pools, or in tandem with the electrofisher in riffles. Sample-site length varied but included predominant habitat types available in the immediate area.

All captured fish were identified and counted. Typically, all specimens of Chihuahua chub were weighed ($\pm$1.0 g) and measured for standard length (SL $\pm$ 1.0 mm). Where large numbers of chubs were collected, only a subsample of those $\leq$50 mm was measured. No specimens $\leq$40 mm were weighed. If possible, specimens were sexed (coloration, tuberculation, and expression of gametes). Incidence of ectoparasites was noted. In Chihuahua, all fish were returned alive to the habitat of collection. Population size structure was characterized and length-weight relationships ($WT = aSL^b$) calculated only for those sites yielding $\geq$20 Chihuahua chub (except Santa Elena and Archuleta/Moreno Spring). Analysis of covariance (ANCOVA) was used to compare length-weight relationships among populations within each basin; SL was the covariate. Specimens were grouped by 10-mm length classes for ANCOVA. Data for length-classes not represented in a collection were estimated from the calculated length-weight relationship for that population. Lack of weights for specimens $\leq$40 mm skewed calculated length-weight relationships.

Macrohabitat at each sample site was classified according to location within the channel, depth, velocity and pattern of water flow, and flow-modifying structures. Macrohabitat types follow Bisson et al. (1981) and Helm (1985). General notes on watershed conditions, land uses, and other factors (e.g., angling) influencing fish populations were recorded.

The scientific collecting permit graciously issued by Secretaria de Desarrollo Urbano y Ecológia (SEDUE) did not authorize retention of voucher specimens. Although we were fairly confident of all identifications, lack of vouchers necessitates qualification of certitude, particularly for regionally rare brown bullhead (*Ameiurus nebulosus*) and previously unreported bullhead minnow (*Pimephales vigilax*). Perhaps more importantly, the specific identity of *Cyprinodon* sp. from several new locations was not determined.

RESULTS—*Distribution, Status, and Associated Species*—Laguna Bustillos Basin—Ten locations on six streams and one reservoir were sampled in the Laguna Bustillos basin (Fig. 2). Sites of fish absence (El Zopilote and arroyos de San Antonio and Ojo Caliente) and low abundance (sites on arroyos de Napavechic and de Santa Elena) were characterized by degraded habitats and supported few or no individuals of any fish species. Irrigated agriculture was widely practiced and long reaches of several streams were dry or existed only as isolated pools. The headwaters of Arroyo de Napavechic were impounded by Presa Benito Juárez.

All three native species (Chihuahua chub, fathead minnow, and *Cyprinodon* sp.) reported by Smith and Miller (1986) were present (Appendix 1). Chihuahua chub were common at only two sites. Non-native beautiful shiner, black bullhead, brown bullhead, and bluegill (*Lepomis macrochirus*) were taken.

Guzmán Basin—Río Santa Clara: Six mainstream and three tributary sites in the Río Santa Clara (=del Carmén) drainage from Santa Catarina to San Lorenzo were sampled. From the vicinity of Ricardo Flores Magón downstream the river was seasonally or permanently dry. Habitats in much of the upstream reach were only slightly modified by human activities; greatest modification was downstream. Dispersed livestock grazing was the primary land use upstream of San Lorenzo.

Smith and Miller (1986) listed Mexican stoneroller (*Campostoma ornatum*), Chihuahua chub,

beautiful shiner, Rio Grande sucker (*Catostomus plebeius*), and *Cyprinodon* sp. as native to the Santa Clara drainage. We frequently collected all native species except *Cyprinodon* sp. Chihuahua chub was moderately common in the upper portion of the river, but uncommon or rare downstream. Non-native common carp, *Cyprinus carpio,* and western mosquitofish, *Gambusia affinis,* were infrequently taken.

Río de Santa Maria: Twelve sites were sampled in the Río de Santa Maria drainage, seven on the Río de Santa Maria from about 8 km south of Bachiniva to 40 km north of Buenaventura and one in each of five spring systems. Dams impounded the river near Bachiniva and Cruces. Downstream of Presa el Tintero, irrigated agriculture was common, particularly north of Buenaventura where lateral canals distributed water over the valley. Chihuahua chub, beautiful shiner, fathead minnow, Rio Grande sucker, and two undescribed *Cyprinodon* sp. were considered native to the drainage (Smith and Miller, 1986). Espinosa-Aguilar (1988) reported an undescribed species of *Catostomus* from the Santa Maria and Casas Grandes drainages. Chihuahua chub was at all riverine sites upstream of Presa el Tintero, and moderately common at two. Nonnative black bullhead and common carp were at the site near Bachiniva and sites downstream of Presa el Tintero. Western mosquitofish was found at downstream sites. Beautiful shiner was in three spring systems and fathead minnow, Rio Grande sucker, and *Cyprinodon* sp. were in one each. Western mosquitofish was the only species common to all spring systems.

Casas Grandes Drainage: Nine species are considered native to the Casas Grandes drainage, an undescribed trout (*Oncorhynchus* sp.), Mexican stoneroller, Chihuahua chub, beautiful shiner, fathead minnow, Rio Grande sucker, an undescribed sucker (*Catostomus* sp.), an undescribed catfish (*Ictalurus* cf. *pricei*), and *Cyprinodon* sp. (Smith and Miller, 1986). Behnke (1992) believed the occurrence of *Oncorhynchus* sp. a result of human introduction from the contiguous Río Yaqui drainage. Siebert and Minckley (1986) tentatively referred the undescribed catostomid to *Catostomus leopoldi,* the Bavispe sucker of the Río de Bavispe (a Río Yaqui tributary), but also stated they had not examined the material upon which Miller (1959) based the occurrence of an undescribed *Catostomus* sp. in the Río Casas Grandes drainage.

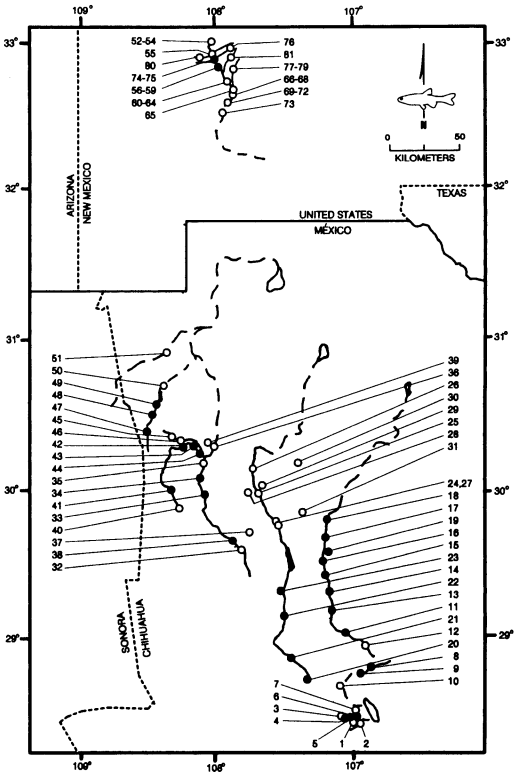

FIG. 2—Sites sampled for Chihuahua chub between 1987 and 1991. Closed circles indicate presence of Chihuahua chub. Numbered collection sites are described in Appendix 1.

Río Casas Grandes: The Casas Grandes drainage was sampled at five riverine locations between Zaragoza (=Río San Miguel) and Casas Grandes, and at one tributary and two springs. Between Zaragoza and El Rusio the river flowed through a canyon where primary land use was livestock grazing. Downstream of El Rusio, rowcrop agriculture was common and by Mata Ortiz much of the flow was seasonally diverted for irrigation; habitat consisted of isolated pools or the channel was dry. No dams impounded the Río Casas Grandes. Chihuahua chub were present at three stream sites and a spring system. The species was moderately common near Zaragoza and El Rusio, where beautiful shiner and Rio Grande sucker were common, Mexican stoneroller was uncommon, and fathead minnow and *Cyprinodon* sp. were rare. At least two non-natives (black bullhead and common carp or western mosquitofish) were at all except the most upstream site at Za-

ragoza where no non-native was found. *Cyprinodon* sp. was in one spring and beautiful shiner, western mosquitofish, and bullhead minnow (*Pimephales vigilax*) were in another.

Río Piedras Verdes: Four sites on the Río Piedras Verdes from Hernández Jovales downstream to Col. Juárez and two on La Tinaja were sampled. Both streams were canyon-bound within the sampled reaches and little habitat modification was noted. Downstream of Juárez, the river was seasonally dry. Timber harvest in headwater areas and dispersed livestock grazing were the main land uses. Five native species, Mexican stoneroller, beautiful shiner, Chihuahua chub, fathead minnow, and Rio Grande sucker, were collected from the two streams, as were three non-native species, rock bass (*Ambloplites rupestris*), bluegill, and black bullhead. Chihuahua chub were common only near Hernández Jovales. No *Cyprinodon* sp. was found. No fish were collected at the upstream site on La Tinaja and only beautiful shiner were taken at the downstream site on this stream.

Río San Pedro: The Río San Pedro (=Río Janos) was sampled at four locations from Cuatro Letras to near Presa Janos. La Palotada, a spring stream peripherally associated with Río San Pedro, was also sampled. Upstream of Presa Janos, dispersed livestock grazing and scattered agriculture were the primary land uses. Downstream of Presa Janos, the channel was dry, with all water diverted for irrigation. Except for the headspring, La Palotada was channelized. Six native and two non-native fish species were found at three locations on the river. Chihuahua chub were at each stream site having fish and were moderately common at one. Non-native largemouth bass (*Micropterus salmoides*) were taken upstream of Presa Janos. Beautiful shiner, fathead minnow, *Cyprinodon* sp., and non-native mosquitofish were found in La Palotada.

Mimbres River: The Mimbres River and four tributaries were sampled at 21 locations from the Cooney Place downstream to Faywood. Several sites were sampled two or more times. The downstream terminus of surface flow varied with season and precipitation, but usually was near Faywood. Within the sampled reach, only the middle portion had continuous flow. None of the tributaries had permanent surface connections to the Mimbres River, and the permanently watered reach of each was ≤8 km long.

Much of the Mimbres River was degraded as a result of livestock grazing, ranchette development, stream channelization (levees), and removal of woody riparian vegetation. Pasturelands, orchards, and cultivated fields bordered the river for most of its course. Comparatively unmodified reaches were uncommon and short. Irrigation diversions seasonally reduced and interrupted surface flow.

The Mimbres River historically supported three native species: beautiful shiner (extirpated since about 1951), Chihuahua chub, and Rio Grande sucker (Koster, 1957; Smith and Miller, 1986). A fourth species, *Oncorhynchus* sp., was suggested by Sublette et al. (1990); no specimens exist to substantiate this occurrence and Behnke (1992) therefore doubted its presence. Reported introduced fishes include Gila trout (*Oncorhynchus gilae*), rainbow trout (*O. mykiss*), brown trout (*Salmo trutta*), longfin dace (*Agosia chrysogaster*), fathead minnow, speckled dace (*Rhinichthys osculus*), channel catfish (*Ictalurus punctatus*), western mosquitofish, green sunfish (*Lepomis cyanellus*), bluegill, longear sunfish (*L. megalotis*), and largemouth bass (Sublette et al., 1990).

Chihuahua chub were found in the Mimbres River from the confluence of Allie Canyon downstream for ≈12 km and in Archuleta/Moreno Spring. The species was not collected at all sites in the occupied reach nor was it common where found; Archuleta/Moreno Spring supported the greatest number of individuals. Rio Grande sucker occurred throughout the Mimbres River and in three tributaries; non-native longfin dace were found in much of the river and rainbow trout and speckled dace were in the upper reaches. Fathead minnow and white crappie (*Pomoxis annularis*) were each taken in one stocktank.

Habitat—In larger streams (ríos de Santa Maria, Santa Clara, and Casas Grandes and Mimbres River), predominant habitat types were runs, glides, and riffles; pools were uncommon and usually associated with root masses of standing or uprooted trees. In smaller streams that flowed through steeper terrain (ríos Piedras Verdes and San Pedro, and Gallinas, East, and Allie canyons), habitats were mainly riffles, shallow runs, and pools in association with boulders or cliffs.

Fish were primarily in habitats associated with streambanks. Lateral scour, backwater, and corner pools usually yielded the greatest number of species and specimens. Exceptions were beautiful shiner, mainly in glides, and Mexican stoneroller, mainly in riffles. The Chihuahua chub was hab-

itat specific. It was most commonly in lateral scour pools where flow was against and along a stream bank or a partial channel obstruction (boulder, cliff, or root wad). The associated scour habitat was typically confined to ≤60% of the wetted channel width. Dimensions varied, but scour pools were usually 4 to 7 m long, 1 to 2 m wide, and about 1 m deep. Water velocity was usually ≤15 cm/s; although immediately adjacent velocity was often ≥60 cm/s. Substrate was commonly gravel. Corner and backwater pools, both with woody material, yielded most of the remaining specimens. Backwater pools were typically downstream of lateral-scour pools and were formed by water eddying around an instream obstruction. Backwater pools were slightly shallower with slower velocity water than lateral-scour pools and had small gravel and sand substrate. Corner pools were a type of lateral-scour pool that formed at sharp bends in the channel where flow cut beneath root masses of woody vegetation. Such pools were common in valleys where the stream meandered and streambanks consisted of incised alluvium. Corner pools were typically ≥10 m long, ≤1 m wide, and ≥1 m deep.

Not only were lateral-scour pools the primary (arealy and numerically) habitat of Chihuahua chub, larger specimens (≥100 mm) were almost exclusively in these areas, particularly those formed by root masses of uprooted and standing trees. Smaller individuals were in corner pools and backwaters only when chubs were abundant at a site. Almost all macrohabitats having chubs were characterized by extensive cover composed of snags and organic debris or root masses of large trees.

Life History Notes—Laguna Bustillos Basin—Three distinct size-groups of Chihuahua chub were present at one site in Arroyo de Napavechic, but the distinction of size-groups at an Arroyo de Santa Elena site was less evident (Fig. 3). The length-weight relationship of the Arroyo de Napavechic population (site 4) was $WT = 0.000046SL^{2.8596}$ ($n = 23$, $r = 0.9845$) whereas that of the Arroyo de Santa Elena (site 9) population was $WT = 0.000056SL^{2.7796}$ ($n = 15$, $r = 0.9978$). The length-weight relationship of the two populations was significantly different ($F = 6.0327$, $P \leq 0.05$). All chubs at other sites in the basin were ≤90 mm. No specimens were sexable at any site. Ectoparasites (*Lernaea* sp. and *Ichthyophthirius* sp.) were found on several specimens.

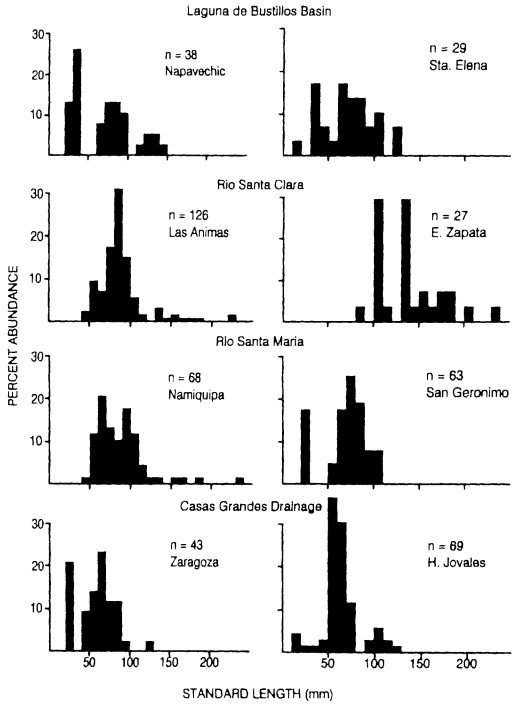

FIG. 3—Length-frequency distribution of Chihuahua chub from eight sites in the Laguna Bustillos and Guzmán basins, Chihuahua, México.

Guzmán Basin—In the Guzmán Basin, the Las Animas (Río Santa Clara) and Namiquipa (Río de Santa Maria) populations of chub had the greatest size range. The length-weight relationship of the Las Animas (site 16) population was $WT = 0.000013SL^{3.0782}$ ($n = 123$, $r = 0.9984$) and that of Namiquipa (site 22) was $WT = 0.000023SL^{2.9782}$ ($n = 67$, $r = 0.9963$). One tuberculate male (155 mm) was collected at Las Animas, and two gravid females (185 and 235 mm) and one tuberculate male (152 mm) were collected at Namiquipa. Leeches and fungal growths were observed on several Las Animas specimens and *Lernaea* sp. was on a few Namiquipa specimens.

No specimen of Chihuahua chub from San Gerónimo (Río de Santa Maria), Zaragoza (Río Casas Grandes), or Hernandez Jovales (Río Piedras Verdes) exceeded 140 mm. Length-weight relationships were $WT = 0.000016SL^{3.0616}$ ($n = 51$, $r = 0.9818$) for San Gerónimo (site 21), $WT = 0.000016SL^{3.0393}$ ($n = 28$, $r = 0.9949$) for Zaragoza (site 32), and $WT = 0.000023SL^{2.9300}$ ($n = 63$, $r = 0.9754$) for Hernandez Jovales (site

41). No specimen from any of these populations was sexable. *Lernaea* sp. was noted on a few individuals from San Gerónimo, but no ectoparasites were observed on specimens from Zaragoza or Hernandez Jovales.

The Emiliano Zapata site (Río Santa Clara, site 15) yielded more large specimens of Chihuahua chub (≥130 mm) than any other site we collected. Sex was determined for 18 of the 27 specimens collected. Males (n = 13) varied from 106 to 154 mm and females (n = 5) from 173 to 207 mm. The length-weight relationship was $WT = 0.000028SL^{2.9419}$ (r = 0.9918).

Analysis of covariance indicated no significant difference in the length-weight relationship among Guzmán basin populations (F = 1.7589, $P \geq 0.001$). The combined length-weight relationship of Guzmán populations $WT = 0.000017SL^{3.0295}$ (n = 358, r = 0.9957).

Mimbres River—On 17 September 1992, 17 specimens of Chihuahua chub were captured from the Archuleta/Moreno Spring. Dense stands of cattail, *Typha* sp., reduced sampling efficiency. Specimens ranged in size from 28 to 237 mm; all but three were ≤100 mm. The length-weight relationship was $WT = 0.000022SL^{2.9722}$ (n = 17, r = 0.9999).

DISCUSSION—Limited information makes determination imprecise for the historic range and abundance of Chihuahua chub. That available suggests the historic range of the species included all but the uppermost portions of permanently watered reaches of the Mimbres River and streams of the Guzmán and Laguna Bustillos basins. Development of water resources for agricultural and municipal uses has caused the downstream termini of these arid-land streams to retreat, and has caused surface flow to become seasonally diminished where water was normally permanent (Brand, 1937). Original collection sites (Baird and Girard, 1854; Girard, 1856) are now dry. Leopold (1940) lamented the degradation of pristine Sierra Madre Occidental streams by encroaching human activity. By the 1950s upland streams of the basin were severely damaged by the effects of uncontrolled logging and pollution from sawmills; harvest of fish with dynamite depleted surviving fish populations (Needham and Gard, 1959). As a result, both range and abundance of the Chihuahua chub have declined dramatically in the past century. For example, R. R. Miller preserved moderate numbers (n = 32) of Chihuahua chub (UMMZ 182397) and W. L. Minckley preserved 81 (ASU 790) in the Río del Carmén near Ricardo Flores Magón in 1964. In 1990, the river was dry in this area and our most downstream collection of Chihuahua chub was 25 km upstream near San Lorenzo, where only three specimens (32, 155, and 235 mm) were collected. In several areas where Chihuahua chub persisted, its abundance had evidently declined. Moderate numbers (n = 16 to 80; UMMZ 185379 and 208257 and ASU 826, 827, 830, and 834) of Chihuahua chub were preserved independently by R. R. Miller and W. L. Minckley from several locations on the Río Piedras Verdes near Col. Juárez in 1964 and 1979, but we found only seven specimens (all ≤60 mm) at three sites in 1990.

Currently, the Chihuahua chub is limited to stream reaches where modification (e.g., channelization and dewatering) and human-induced habitat degradation (e.g., livestock overgrazing, municipal and agricultural pollution) are minimal. Such areas are uncommon. We found Chihuahua chub at 28 of 40 stream sites having fish, in one of nine spring sites, and at neither of two lakes sampled in Chihuahua. It was moderately common (≥10% of specimens) at 12 of the stream sites, but <30 chubs were collected at six of these. In the Mimbres Drainage, the Chihuahua chub was regularly found only in Archuleta/Moreno Spring and was not common there.

The presence and abundance of pools associated with root masses of uprooted or standing large trees seemed the character that best predicted occurrence and abundance of Chihuahua chub. The Mimbres River and all streams in the Laguna Bustillos basin were greatly modified (channelized and discontinuous flow) from their historic condition as described by Antisell (1857) and Brand (1937), respectively. During our visits, there were few large trees bordering the streams. The Chihuahua chub was absent or rare in these systems. Chihuahua chub were moderately common only in remote and relatively unmodified portions of the ríos Santa Clara, Santa Maria, and Casas Grandes where mature stands of cottonwood, *Populus* sp., were fairly common. Where cultivated fields bordered the stream or where towns were nearby, large riparian trees were uncommon and no snags or root masses were in the stream; Chihuahua chub was uncommon or absent and individuals were small (≤75 mm).

Presence of non-native fishes also seemed to

influence occurrence and abundance of the Chihuahua chub. It was rare or absent where habitat was degraded and non-native fishes were common. If present, individuals were always small. Chihuahua chub was similarily uncommon where habitat was not severely degraded but non-natives were present (e.g., sites in middle reaches of the Río Piedras Verdes).

Few samples of Chihuahua chub yielded a broad size-range of individuals; most individuals were 50 to 100 mm. Among the eight Chihuahua populations whose size structure was characterized, the presence of multiple size classes indicated successful recruitment. If the size range of individuals found at each site accurately reflected population size structure, most reproduction was accomplished either by individuals <130 mm or by a very few >150 mm. Length-weight relationships among characterized populations in the Guzmán basin were not significantly different, while the two characterized populations in the Bustillos basin were. All populations had near-isometric growth (standard length exponents ≈ 3.0).

Few specimens (n = 22) were sexed, but of these, males were smaller (106 to 155 mm, n = 15) than females (173 to 285 mm, n = 7). The occurrence of ripe males and gravid females during March at several lower elevation sites and presence of individuals <20 mm at higher elevation sites, suggested that Chihuahua chub has an extended spawning season. Spawning season probably varies among streams and within a stream may vary longitudinally and yearly, but plausibly encompasses early spring through early autumn. Another species of *Gila* occurring at similar latitudes also exhibits extended spawning seasons (Hendrickson and Juárez-Romero, 1990).

The distribution of Chihuahua chub and the size of individuals collected suggested that populations in each stream were maintained by a "core" population. Where Chihuahua chub were rare, individuals were typically small. We suspect that these fish were derived from reaches where numbers of adults were greater, rather than from the immediate vicinity of collection. This pattern of one or a few locations, generally in remote upstream areas, having comparatively large numbers of Chihuahua chub of several size classes and occurrence of a few small individuals at downstream sites was noted in all sampled streams.

Rarity of larger individuals of Chihuahua chub in some areas with apparently suitable habitat may be due to their capture for human consumption. At several sites in Chihuahua we found evidence of, or witnessed, rather imaginative capture techniques (torches and sharpened poles for night harvest and holes bored through root masses to enable a person to frighten fish from cover into strategically placed homemade metal-screen "seines"). Children keenly observing us were often dismayed when we returned chubs alive to the stream and admonished us that *charalitos* were the most desirable food fish in the stream.

While our efforts provide an overview of current distribution and abundance of Chihuahua chub in New Mexico and Chihuahua, status of the species in areas we did not sample should be determined. Much remains to be learned about the biology and habitat associations of Chihuahua chub, and its interactions with non-native fishes. Furthermore, the taxonomic status and relationships among isolated populations in the Laguna Bustillos and Guzmán basins and the Mimbres River requires clarification.

The native fish fauna was depauperate in streams where Chihuahua chub was historically found. The Mimbres River and Laguna Bustillos drainages had only three natives each, and the ríos Santa Clara, Santa Maria, and Casas Grandes drainages had five to nine. None has yet become extinct, but all have experienced reductions in range and abundance. All of the principal causes of loss of native aquatic biodiversity (Cairns and Lackey, 1992), habitat destruction, degradation, and fragmentation, and pollution, nonnative species, and overharvest, apply to these streams. The loss of the native aquatic biodiversity in this region seems likely to continue.

The persistence of Chihuahua chub in the wild will depend upon remote reaches where either topography or land ownership discourages additional human settlement and water resource development. Such areas are uncommon, fragmented, and represent a small fraction of the historic range of the species. In the United States, only a few small individuals were found in the degraded habitats of the Mimbres River. In this drainage, Chihuahua chub survived only because Archuleta/Moreno Spring was unmodified. Stream dewatering and habitat destruction may soon cause extirpation of Chihuahua chub from limited habitats of the Laguna Bustillos Basin. In the Guzmán basin, Chihuahua chub may survive only in remote reaches of the ríos Santa Clara, Santa Maria, Casas Grandes, and Piedras

Verdes. Even in these areas, threats continue from non-native species, pollution, uncontrolled logging, and overharvest. The future of the Chihuahua chub is bleak.

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APPENDIX 1

Fishes collected at sites in the Laguna Bustillos Basin, ríos Santa Clara, Santa Maria, and Casas Grandes drainages, and the Mimbres River drainage, New Mexico. Species codes are: Ac = *Agosia chrysogaster,* Am = *Ameiurus melas,* An = *Ameiurus nebulosus,* Ar = *Ambloplites rupestris,* Cc = *Cyprinus carpio,* Cf = *Cypinella formosa,* Co = *Campostoma ornatum,* Cp = *Catostomus plebeius,* Cs = *Cyprinodon* sp., Ga = *Gambusia affinis,* Gn = *Gila nigrescens,* Lm = *Lepomis macrochirus,* Ms = *Micropterus salmoides,* Om = *Oncorhynchus mykiss,* Pa = *Pomoxis annularis,* Pp = *Pimephales promelas,* Pv = *Pimephales vigilax,* Ro = *Rhinichthys osculus.* Each locality description is followed by elevation, latitude (N), longitude (W), date of collection, total number of fish collected (n), and species collected, with their relative abundance (%). Site numbers correspond with those shown in Fig. 2.

Laguna Bustillos Basin—1. El Zopilote, 2,100 m, 28°28′, 107°01′, 5 March 1990, n = 0. 2. Arroyo de San Antonio, 5.1 km NNE Cuauhtémoc, 2,042 m, 28°28′, 106°50′, 6 March 1990, n = 0. 3. Presa Benito Juárez, 2,195 m, 28°28′, 107°01′, 6 March 1990, n = 164—Am (1.2), An (0.6), Cf (92.7), Lm (3.7), Pp (1.8). 4. Arroyo de Napavechic below Presa Benito Juárez, 2,195 m, 28°28′, 107°01′, 6 March 1990, n = 58—Am (3.5), An (3.5), Cf (43.1), Cs (12.1), Gn (34.5), Pp (3.5). 5. Arroyo de Napavechic, 2 km W Napavechic, 2,103 m, 28°28′, 106°58′, 6 March 1990, n = 26—Cs (88.5), Gn (3.9), Pp (11.5). 6. Arroyo de Napavechic at MEX 23 bridge, 10 km N CHI 16, 2,042 m, 28°29′, 106°54′, 7 March 1990, n = 129—Cf (24.8), Cs (9.3), Gn (28.7), Pp (37.2). 7. Arroyo Ojo Caliente at MEX 23 bridge, 2,012 m, 28°34′, 106°54′, 7 March 1990, n = 0. 8. Arroyo de Santa Elena, 100 m SW Campo 35, 2,045 m, 28°49′, 106°51′, 8 March 1990, n = 22—Cf (50.0), Cs (18.2), Gn (27.3), Pp (4.6). 9. Arroyo de Santa Elena, 3 km NW Alvaro Obregón, 2,021 m, 28°46′, 106°56′, 8 March 1990, n = 37—Cf (21.6), Gn (70.3), Pp (8.1). 10. Tributary to Laguna Morelas, 2 km S Campo 105, 2,012 m, 28°42′, 107°01′, 8 March 1990, n = 0.

Río Santa Clara Drainage—11. Tributary to Río Santa Clara, 5 km WSW Benito Juárez, 2,000 m, 29°08′, 106°52′, 20 March 1990, n = 46—Cf (6.5), Co (32.6), Cp (4.4), Gn (56.5). 12. Tributary to Río Santa Clara at Tepehuanes, 2,057 m, 29°05′, 106°48′, 20 March 1990, n = 91—Co (74.7), Cp (25.3). 13. Río Santa Clara, 6.5 km N Santa Catarina at bridge, 1,920 m, 29°14′, 106°59′, 20 March 1990, n = 232—Cf (12.5), Co (9.1), Cp (58.2), Cs (12.1), Gn (8.2). 14. Río Santa Clara, 6 km N Santa Clara at El Camposanto, 1,859 m, 29°21′, 107°01′, 21 March 1990, n = 340—Cc (0.6), Cf (24.7), Co (2.4), Cp (69.1), Cs (1.2), Gn (2.1). 15. Río Santa Clara, 2 km N Emiliano Zapata, 1,829 m, 29°25′, 107°02′, 21 March 1990, n = 76—Cf (4.0), Cp (57.9), Gn (38.2). 16. Río Santa Clara at Las Animas, 1,768 m, 29°34′, 107°04′, 21 March 1990, n = 359—Cf (2.5), Co (0.6), Cp (62.1), Gn (34.8). 17. Río Santa Clara, 6 km W Mesa Juan Largo, 1,707 m, 29°36′, 107°05′, 22 March 1990, n = 113—Cc (7.1), Cf (29.2), Co (9.7), Cp (47.8), Gn (6.2). 18. Río Santa Clara, 4 km S San Lorenzo, 1,585 m, 29°47′, 107°04′, 22 March 1990, n = 74—Cc (1.4), Cf (8.1), Co (4.1), Cp (33.8), Cs (1.4), Ga (47.3), Gn (3.6). 19. Los Frailes, tributary to Río Santa Clara, 1,798 m, 29°34′, 107°03′, 22 March 1990, n = 118—Co (16.1), Cp (80.5), Gn (3.4).

Río Santa Maria Drainage—20. Río Santa Maria, 6 km S Bachiniva, 2,073 m, 28°43′, 107°15′, 9 March 1990, n = 210—Am (0.5), Cc (4.8), Cf (22.4), Cp (19.1), Cs (11.4), Gn (5.7). 21. Río Santa Maria at San Gerónimo, 1,859 m, 28°58′, 107°23′, 9 March 1990, n = 315—Cf (10.5), Cp (55.2), Gn (33.0), Pp (1.3). 22. Río Santa Maria, 100 m S of bridge, 1,798 m, 29°14′, 107°24′, 11 March 1990, n = 215—Cf (0.5), Cp (41.9), Gn (39.1), Pp (18.6). 23. Río Santa Maria,

1 km S Cruces, 1,715 m, 29°26′, 107°24′, 11 March 1990, *n* = 85—Cf (18.8), Cp (30.6), Gn (2.4), Pp (48.2). 24. Río Santa Maria, 3.5 km S Buenaventura, 1,554 m, 29°49′, 107°27′, 13 March 1990, *n* = 94—Cf (7.5), Cp (87.2), Pp (5.3). 25. Río Santa Maria, 1 km W Angostura, 1,463 m, 30°02′, 107°36′, 14 March 1990, *n* = 73—Cc (17.8), Ga (80.1), Pp (1.4). 26. Río Santa Maria at CHI 10 bridge, 1,411 m, 30°11′, 107°08′, 14 March 1990, *n* = 27—Am (18.5), Ga (55.6), Pp (25.9). 27. Springs 2 km S Buenaventura, 1,400 m, 29°49′, 107°27′, 13 March 1990, *n* not recorded—Cf, Cp, Ga. 28. Ciénega de Horcones, 4 km W Angostura, 1,463 m, 30°02′, 107°37′, 14 March 1990, *n* = 67—Ga (100). 29. Ojo de Galeana, hot spring baths 2 km NE Angostura, 1,463 m, 30°04′, 107°35′, 14 March 1990, *n* = 634—Cf (4.4), Cs (57.6), Ga (38.0). 30. Spring stream at Ojo Narriz, 48 km N Ojo Caliente, 1,341 m, 30°15′, 107°21′, 15 March 1990, *n* = 253—Cf (1.2), Ga (72.3), Pp (26.5). Springhead at Ojo Servin, 5 km W Ojo Caliente, 1,585 m, 29°53′, 107°17′, N not recorded—Ga (100).

Río Casas Grandes—32. Arroyo de San Miguel, 1 km W Zargosa, 2,042 m, 29°39′, 107°46′, 12 March 1990, *n* = 2,767—Cf (29.0), Co (2.0), Cp (66.9), Cs (0.2), Gn (2.2). 33. Río Casas Grandes, 6.4 km S El Rusio, 1,676 m, 30°00′, 108°01′, 26 March 1990, *n* = 129—Am (3.1), Cc (1.6), Cf (45.7), Co (3.9), Cp (24.0), Gn (20.2). 34. Río Casas Grandes, 5.3 km S Mata Ortiz, 1,585 m, 30°08′, 108°02′, 27 March 1990, *n* = 201—Am (0.5), Cc (1.5), Cf (52.2), Co (5.0), Cp (38.8), Gn (2.0). 35. Río Casas Grandes at Hacienda San Diego, 9 km N Mata Ortiz, 1,524 m, 30°14′, 108°00′, 27 March 1990, *n* = 56—Am (5.4), Cc (10.7), Cf (26.2), Co (10.7), Cp (30.4). 36. Río Casas Grandes, 7 km S Nuevo Casas Grandes, 1,494 m, 30°21′, 107°56′, 23 March 1990, *n* = 40—Am (5.0), Cf (10.0), Cp (62.5), Ga (22.5). 37. Impoundment at Tres Ojitas, NNE Zaragosa, 2,195 m, 29°45′, 107°42′, 12 March 1990, *n* = 20—Cs (100). 38. Ojo de Piedra, springstream 5 km NNW Zaragosa, 2,042 m, 29°41′, 107°47′, 12 March 1990, *n* = 97—Cf (37.1), Co (9.3), Cp (51.6), Gn (2.1). 39. Ojo Vareleño, springstream 4 km NW Casas Grandes, 1,494 m, 30°24′, 107°59′, 23 March 1990, *n* = 201—Cf (7.5), Ga (89.1), Pv (3.5). 40. Río Piedras Verdes at Ejido Playas, 2,316 m, 29°55′, 108°17′, 29 March 1990, *n* = 0. 41. Río Piedras Verdes, 1 km S Hernández Jovales, 2,042 m, 30°02′, 108°18′, 29 March 1990, *n* = 319—Cf (27.0), Co (14.4), Cp (28.5), Gn (30.1). 42. Río Piedras Verdes, 15.6 km W Col. Juárez, 1,676 m, 30°19′, 108°11′, 28 March 1990, *n* = 107—Am (6.5), Ar (5.6), Cf (48.6), Co (8.4), Cp (25.2), Gn (3.7), Pp (1.9). 43. Río Piedras Verdes, 8.2 km WNW Col. Juárez, 1,600 m, 30°20′, 108°07′, 28 March 1990, *n* = 177—Am (4.0), Ar (1.7), Cf (29.4), Co (22.6), Cp (40.1), Gn (1.1). 44. Río Piedras Verdes in Col. Juárez, 0.5 km NW of bridge, 1,585 m, 30°18′, 108°04′, 28 March 1990, *n* = 137—Cf (22.6), Co (51.1), Cp (25.6), Gn (0.7). 45. La Tinaja, 1,768 m, 30°23′, 108°14′, 27 March 1990, *n* = 0. 46. La Tinaja, 1,707 m, 30°22′, 108°10′, 27 March 1990, *n* = 19—Cf (100). Río San Pedro, 3.1 km S Cuatro Letras, 1,676 m, 30°28′, 108°29′, 24 March 1990, *n* = 203—Cf (30.5), Co (8.9), Cp (57.1), Gn (3.5). 48. Río San Pedro, 1 km S Lazaro Cardenas, 1,646 m, 30°33′, 108°28′, 24 March 1990, *n* = 356—Cf (4.5), Co (26.1), Cp (56.7), Cs (0.3), Gn (12.1), Pp (0.3). 49. Río San Pedro, 5.1 km N Lazaro Cardenas, 1,615 m, 30°36′, 108°28′, 25 March 1990, *n* = 130—Cf (29.2), Co (5.4), Cp (57.7), Gn (6.2), Ms (0.8), Pp (0.8). 50. Río San Pedro, 4.5 km N Presa Janos, 1,494 m, 30°43′, 108°26′, 25 March 1990, *n* = 0. La Palotada, 15 km W Janos on MEX 2, 1,356 m, 30°57′, 108°19′, 25 March 1990, *n* = 77—Cf (74.0), Cs (10.4), Ga (14.3), Pp (1.3).

Mimbres River Drainage—52–75. Mimbres River, Grant County, 1987–1990, *n* not recorded—Ac, Cp, Gn, Om, Ro, Pp. 76. East Canyon, Grant County, 2,158 m, T15S, R11W, Sec. 24, 13 March 1991, *n* not recorded—Cp, Om. 77–79. Gallinas Canyon, Grant County, 12 April 1989, *n* not recorded—Ac, Cp, Om. 80. Allie Canyon, Grant County, T16S, R12W, Sec. 17, 1 June 1988, *n* not recorded—Ac, Cp. 81. Noonday Canyon, Grant County, 2,060 m, T16S, R10W, Sec. 22, 2 June 1988, *n* = 0.